
PART I.

THE NATURAL HISTORY OF PETROLEUM,

TOGETHER WITH

A DESCRIPTION OF THE METHODS EMPLOYED IN THE PRODUCTION, TRANSPORTATION,
AND SALE OF PETROLEUM IN THE UNITED STATES,

AND

STATISTICS OF THE PRODUCTION OF PETROLEUM IN THE
UNITED STATES AND FOREIGN COUNTRIES

DURING THE

YEAR ENDING MAY 31, 1880.

PART I.

CHAPTER I.—HISTORY OF THE DISCOVERY OF PETROLEUM AND THE DEVELOPMENT OF THE PETROLEUM INDUSTRY.

SECTION I.—HISTORICAL NOTICE OF BITUMEN PRIOR TO THE YEAR 1800.

The word petroleum means rock-oil, and in its present form it is adopted into English from the Latin. Its equivalents in German are *Erdöl* (earth-oil) and *Steinöl* (stone-oil); in French and the other languages of southern Europe the word is *Pétrole*—equivalent to petroleum. Within a few years the Germans have also used the word "petroleum".

Petroleum is one of the forms of bitumen, and cannot be discussed historically except in connection with the other forms. These are:

Solid: Asphaltum.—German, *Asphalt*, *Erdharz*, or *Erdpech*; French, *Asphalte*.

Semi-fluid: Maltha.—French, *Goudron minéral*; Spanish, *Brea*.

Fluid: Petroleum; Volatile: Naphtha.—German, *Naphta*, from Persian *Nafta* or *Neft gil*.

Gaseous: Natural gas.—Of burning springs.

The word *Nafta* appears to have been used by the Persians, and its equivalent, *Naphtha*, has been frequently used in European literature to designate what is now called petroleum, and not the most volatile form of fluid bitumen occurring in nature. Solid bitumen is to be distinguished from coal in the manner of its occurrence, and also by the action of various solvents, especially benzole and carbon disulphide, which dissolve asphaltum, but have no action upon coal.

Bitumen has been known and applied to the uses of mankind from the dawn of history. Its very wide distribution has led to its frequent notice by observers of natural phenomena, and the records of such observations have been as widely extended as the occupation of the earth by civilized man. Herodotus wrote of the springs in the island of Zante as follows:

I have myself seen pitch drawn up out of a lake and from water in Zacynthus; and there are several lakes there; the largest of them is seventy feet every way, and two orgyæ in depth; into this they let down a pole with a myrtle branch fastened to the end, and then draw up pitch adhering to the myrtle; it has the smell of asphalt, but is, in other respects, better than the pitch of Pieria. They pour it into a cistern dug near the lake, and when they have collected a sufficient quantity they pour it off from the cisterns into jars. (a)

The springs called Oyun Hit (the fountains of Hit) are celebrated by the Arabs and Persians, the latter calling them *Cheshmeh Kir* (the fountain of pitch). This liquid bitumen they call *Nafta*; and the Turks, to distinguish it from pitch, give it the name of *Hara sakir* (black mastic). Nearly all modern travelers who went to Persia and the Indies by way of the Euphrates before the discovery of the cape of Good Hope speak of this fountain of bitumen. Herodotus mentions that "eight days' journey from Babylon stands another city called Is, on a small river of the same name, which discharges its stream into the Euphrates. Now this river brings down with its water many lumps of bitumen, from whence the bitumen used in the wall of Babylon was brought". (b)

The people of the country have a tradition that when the tower of Babel was building they brought the bitumen from hence. At the pits of Kir ab ur Susiana bitumen is still collected in the same manner as related by Herodotus. (c) He says:

At Ardericca is a well which produces three different substances, for asphalt, salt, and oil are drawn up from it in the following manner: It is pumped up by means of a swipe, and, instead of a bucket, half a wine skin is attached to it. Having dipped down with this, a man draws it up, and then pours the contents into a reservoir, and, being poured from this into another, it assumes these different forms: the asphalt and the salt immediately become solid, but the oil they collect, and the Persians call it *Rhadinnace*; it is black, and emits a strong odor.

a Herodotus, i, 119, iv, 195; B. S. G. F., xxv, 62; J. S. A., vii, 639. b *Ibid.*, i, 179; J. S. A., vii, 639, 640. c *Ibid.*, vi, 119.

Strabo (*a*) mentions the occurrence of bitumen in the valley of Judea, and describes the commerce carried on in this article by the Arab Nabathenes with the Egyptians for the purpose of embalming; also the manner of its occurrence, rising during or after earthquake shocks to the surface of the Dead sea and forming masses resembling islands. Diodorus, of Sicily, describes the lake Asphaltites and the manner in which the savage inhabitants of the country construct rafts, and continues:

These barbarians, who have no other kind of commerce, carry their asphalt to Egypt and sell it to those who make a profession of embalming bodies, because, without the mixture of this material with the other aromatics, it would be difficult for them to preserve them for a long time from the corruption to which they are liable. (*b*)

This bitumen, with that from the springs of Hit, on the Euphrates, of which Eratosthenes has given such interesting details, and which served to cement the bricks of Babylon, is also used for coating ships, (*c*) and is still used in our own time for coating boats on the Euphrates. (*d*)

The semi-fluid bitumen was used in the construction of Nineveh and Babylon to cement bricks and slabs of alabaster, and the grand mosaic pavements and beautifully inscribed slabs used in the palaces and temples of these ancient cities, many of which were of enormous size, were fastened in their places with this material. It was also used to render cisterns and silos for the preservation of grain water-tight, and some of these structures of unknown antiquity are still found intact in the ancient cities of Egypt and Mesopotamia. The naphtha is more highly valued than the solid bitumen, the most fluid varieties being used in lamps. The Persians also manufacture dried dung in long sticks, which are dipped in naphtha and burned for lights, and it is also used for cooking and heating; but in order to avoid the unendurable smell a peculiar kind of chimney is carried into each room. Cotton wicks are also used in naphtha to some extent. The white or colorless naphtha, which is most rare, is used by the apothecaries. (*e*)

Aristotle, Strabo, Plutarch, Pliny, and others describe at some length deposits of bitumen occurring in Albania, on the eastern shores of the Adriatic sea, (*f*) and similar notices of petroleum springs and gas wells in China occur in the earliest records of that ancient people. Pliny and Dioscorides described the oil of Agrigentum, which was used in lamps, under the name of "Sicilian oil".

The soft bitumen in the Euphrates valley is that of which we have the earliest mention. (*g*) The word translated *slime* in the English version of Genesis xi, 3, is *ἄσφαλτος* in the Septuagint and *bitumen* in the Vulgate, and this is what is meant. The great abundance of petroleum at Baku, on the Caspian sea, and the remarkable sight presented by the flaming streams of oil and discharges of gas, have been the subject of many descriptions. The fire temple at Baku has had a special interest in connection with India, not only from its general similarity to that of Jawálamúhki, near Kangra, in the Punjab, (*h*) but also from the circumstance that the Baku temple has for a long time and down to the present day been, like the other, a place of Hindoo pilgrimage. The great conflagrations of oil upon the ground have not been constant, and hence many travelers do not mention them.

Marco Polo describes the great abundance of the discharges of oil at Baku, and says that people came from a vast distance to collect it. (*i*) Baku is described by Kaempfer, who was there in 1684. (*j*) In 1784 it was visited by Forster, on his journey from India to England, who has given an account of the place and of the Hindoo merchants and mendicants residing there.

Between Kaempfer and Forster came Jonas Hanway, who gives a description of Baku, the fire temple, and the Hindoos, and the great quantities of oil obtained at that time, chiefly from certain islands in the Caspian sea. Descriptions are given by other travelers, ancient and modern, of this oil region, (*k*) of the copious discharges of white and black naphtha, the streams of flaming oil on the hillsides, the gas and the fire temple, and the explosive effects of the ignition of the gas mixed with atmospheric air. (*l*)

A tradition is preserved in Plutarch that a Macedonian who had charge of Alexander's baggage is said to have dug on the banks of the Oxus: "There came out, which differed nothing from natural oil, having the glosse and fatness so like as there could be discovered no difference between them." (*m*)

a Tome XVI, ch. ii.

b Tome I L, II., cap. xxix.

c Strabo, I, xvi, cxii.

d Lartet, B. S. G. F., xxiv, p. 12.

e Ritter's *Erdkunde*, II, 578.

f Strabo, VI, 763; Pliny, N. H., VII, 13; Josephus, B. I., IV, 8, 4; Tacitus, Hist., V, 6; Mandeville, Rochon, etc. Plutarch: Life of Sylla; Dion Cassius, Rom. Hist. c. XLI; Ælian Varie Hist., XIII, 16; quoted in B. S. G. F., xxv, 21.

g Herod., I, 179; Philostr. Apoll. Tyan., I, 17; D'Herbelot, Biblioth. Or. o. v. Hit.

h G. T. Vigne, *Travels in Cashmir and Little Thibet*, 1842, p. 133.

i Book I, ch. III (vol. I, p. 46, Col. Yule's ed., 1871), note in Marsden's ed.

j Amoenit. Exot., p. 224. Colburn's Nat. Libr., i, 263.

k *Wonders of the East*, by Friar Jordanus, p. 50 (Colonel Yule's note); *Keppel's Journey from India to England*, 1824; *A Journey from London to Persepolis*, by J. Usher, 1865; Morier's *Journey*; Kinneir's *Persia*; *Some Years' Travels*, by Tho. Herbert, 1638.

l I am indebted for many of the preceding facts and references to an excellent article on "Naphtha" by M. C. Cooke, J. S. A., vii, 638; also, Colonel R. MacLagan, on the "Geographical Distribution of Petroleum and Allied Products", P. B. A. A. S., 1871, 180.

m Sir Thomas North's translation of *Plutarch's Lives*, ed. 1631, p. 702.

The occurrence of petroleum in North America was noticed by the earliest explorers, as the Indians dwelling in the vicinity of the great lakes applied it to several purposes, and thus brought it to the attention of those who went among them; but the earliest mention that has come under my notice is of 1629. A Franciscan missionary, Joseph de la Roche D'Allion, who crossed the Niagara river into what is now the state of New York, wrote a letter, in which he mentions the oil-springs and gives the Indian name of the place, which he explained to mean, "There is plenty there." This letter was published in Sagard's *Histoire du Canada*, 1632, and subsequently in *Le Clerc*.

Peter Kalm published in Swedish about the middle of the last century a book of travels, in which was a map, on which the springs on Oil creek were properly located. This book has been translated into English, and an edition was published in London in 1772.

In the first volume of the *Massachusetts Magazine*, published in 1789, appears the following notice: (a)

In the northern part of Pennsylvania is a creek called Oil creek, which empties into the Allegheny river. It issues from a spring, on which floats an oil similar to that called Barbadoes tar, and from which one may gather several gallons in a day. The troops sent to guard the western posts halted at this spring, collected some of the oil, and bathed their joints with it. This gave them great relief from the rheumatism with which they were afflicted. The water, of which the troops drank freely, operated as a gentle purge.

The earliest records of voyages and travels among the Seneca Indians who occupied northwestern Pennsylvania and southwestern New York contain observations respecting the reverence paid the oil-springs of Oil creek and the contiguous valleys by this people, not only using it for medicinal purposes, but also in religious observances.

The French commander of Fort Duquesne in the year 1750 writes as follows to General Montcalm:

I would desire to assure you that this is a most delightful land. Some of the most astonishing natural wonders have been discovered by our people. While descending the Allegheny, fifteen leagues below the mouth of the Conewango and three above the Venango, we were invited by the chief of the Senecas to attend a religious ceremony of his tribe. We landed, and drew up our canoes on a point where a small stream entered the river. The tribe appeared unusually solemn. We marched up the stream about half a league, where the company, a band it appeared, had arrived some days before us. Gigantic hills begirt us on every side. The scene was really sublime. The great chief then recited the conquests and heroism of their ancestors. The surface of the stream was covered with a thick scum, which, upon applying a torch at a given signal, burst into a complete conflagration. At the sight of the flames the Indians gave forth the triumphant shout that made the hills and valleys re-echo again. Here, then, is revived the ancient fire-worship of the East; here, then, are the children of the Sun. (b)

In 1765 the English government sent an embassy to the court of Ava, in Burmah. In the journal of that embassy, by Major Michael Symes, may be found a description of the petroleum wells in the neighborhood of Yenangyoung (Earth-oil creek), a small tributary of the Irrawaddy. For an unknown period the whole of Burmah and portions of India have been supplied with illuminating oil from this source, particularly those regions that are reached by the Irrawaddy and its tributaries.

On page 261 of Symes' *Journal* we read:

After passing various lands and villages, we got to Yenangyoung, or Earth-oil creek, about two hours past noon. We were informed that the celebrated wells of petroleum which supply the whole empire and many parts of India with that useful product were five miles to the east of this place. The mouth of the creek was crowded with large boats waiting to receive a lading of oil, and immense pyramids of earthen jars were raised in and around the village, disposed in the same manner as shot and shell are piled in an arsenal. This is inhabited only by potters, who carry on an extensive manufactory and find full employment. The smell of the oil is extremely offensive. We saw several thousand jars filled with it ranged along the bank; some of these were continually breaking, and the contents, mingling with the sand, formed a very filthy consistence.

Late in the last century springs of petroleum were noticed in West Virginia, in Ohio, and in Kentucky, as explorers and settlers began to penetrate the country west of the Alleghany mountains.

SECTION 2.—HISTORICAL NOTICE OF BITUMEN FROM THE YEAR 1800 TO 1850.

In Europe, early in the present century, chemists examined the bitumen of the Val de Travers. (c) The gas springs of Karamania, noticed by Otesias more than two thousand years before, again attracted attention, (d) and the asphalt deposits of Albania, mentioned by Strabo and Pliny, were again described by Pouqueville. (e)

In 1811 Dr. Nicholas Nugent visited the West Indies, and on his return to England wrote an account of the famous pitch lake of Trinidad, near the mouth of the river Orinoco. (f) He described the wonderful beauty of the tropical island, with its more wonderful lake of solid yet plastic bitumen, on which were pools of water containing fish and islands of verdure thronged with brilliant birds.

From 1820 to 1830 remarkable activity was manifested in the investigation of the nature and occurrence of bituminous substances. The Hon. George Knox read a communication to the Royal Society of Great Britain, in which he noticed the wide distribution of these substances in nature, and the fact that even so-called eruptive rocks

a Am. C., iii, 174.

b Henry's *Early and Later History of Petroleum*, p. 11.

c De Saussure, A. C. N. P. (2), iv, 314, 620, 308.

d Beaufort: *Survey of the Coast of Karamania*, 1820, p. 24.

e *Voyage en Grèce*, 1820, 1, 271; B. S. G. F., xxv, 22.

f T. G. S., (1) 1, 63.

were rarely found entirely destitute of bitumen as an ingredient. This paper attracted much attention. (a) In 1824 Reichenbach discovered paraffine in the products of the destructive distillation of wood, (b) and in the following year Gay-Lussac analyzed it. (c)

In 1826 the British government sent a second embassy to Ava, and in the journal of that embassy the ambassador, Hon. John Crawfurd, again describes the petroleum wells of Rangoon, and furnishes many details respecting the method of their operation and the amount of their product. (d)

Boussingault investigated the bitumen of Pechelbronn, on the lower Rhine, and compared its peculiarities with those of bitumens from other localities. His work on these substances became very celebrated, and has been very widely quoted. (e) These researches created a lively interest in France, and led to much experimenting upon both solid and liquid bitumens, with a view to ascertaining the purposes to which they might be applied.

During this period the first well was bored in the United States that produced petroleum in any considerable quantity. As the first well bored or drilled for brine was the legitimate precursor of all the petroleum wells in the country, an historical account of it is introduced here, taken from a paper written by Dr. J. P. Hale, of Charleston, West Virginia, for the volume prepared by Professor M. F. Maury, and issued by the State Centennial Board, on the resources and industries of the state. He says:

It was not until 1806 that the brothers, David and Joseph Ruffner, set to work to ascertain the source of the salt water, to procure, if possible, a larger supply and of better quality, and to prepare to manufacture salt on a scale commensurate with the growing wants of the country.

The Salt Lick, or "the Great Buffalo Lick", as it was called, was just at the river's edge, 12 or 14 rods in extent, on the north side, a few hundred yards above the mouth of Campbell's creek, and just in front of what is now known as the "Thoroughfare Gap", through which, from the north, as well as up and down the river, the buffalo, elk, and other ruminating animals made their way in vast numbers to the lick. * * *

In order to reach, if possible, the bottom of the mire and oozy quicksand through which the salt water flowed they (the Ruffner brothers) provided a straight, well-formed, hollow sycamore tree, with 4 feet internal diameter, sawed off square at each end. This is technically called a "gum". This gum was set upright on the spot selected for sinking, the large end down, and held in its perpendicular position by props or braces on the four sides. A platform, upon which two men could stand, was fixed about the top; then a swape was erected, having its fulcrum in a forked post set in the ground close by. A large bucket, made from half of a whisky barrel, was attached to the end of the swape by a rope, and a rope was attached to the end of the pole, to pull down on, to raise the bucket. With one man inside the gum, armed with pick, shovel, and crowbar, two men on the platform on top to empty and return the bucket, and three or four to work the swape, the crew and outfit were complete.

After many unexpected difficulties and delays the gum at last reached what seemed to be rock bottom at 13 feet. Upon cutting it with picks and crowbars, however, it proved to be but a shale or crust about 6 inches thick of conglomerated sand, gravel, and iron. Upon breaking through this crust the water flowed up into the gum more freely than ever, but with less salt.

Discouraged at this result, the Ruffner brothers determined to abandon this gum and sink a well out in the bottom, about 100 yards from the river. This was done, encountering, as before, many difficulties and delays. When they had gotten through 45 feet of alluvial deposit they came to the same bed of sand and gravel upon which they had started at the river. To penetrate this they made a 3½-inch tube of a 20-foot oak log by boring through it with a long-shanked auger. This tube, sharpened and shod with iron at the bottom, was driven down, pile-driver fashion, through the sand to the solid rock. Through this tube they then let down a glass vial with a string, to catch the salt water for testing.

They were again doomed to disappointment. The water, though slightly brackish, was less salt than that at the river. They now decided to return to the gum at the river, and, if possible, put it down to the bed-rock. This they finally succeeded in doing, finding the rock at 16 to 17 feet from the surface.

As the bottom of the gum was square and the surface of the rock uneven, the rush of outside water in the gum was very troublesome. By dint of cutting and trimming from one side and the other, however, they were at last gotten nearly to a joint, after which they resorted to thin wedges, which were driven here and there as they would "do the most good".

By this means the gum was gotten sufficiently tight to be so bailed out as to determine whether the salt water came up through the rock. This turned out to be the case. The quantity welling up through the rock was extremely small, but the strength was greater than any yet gotten, and this was encouraging. They were anxious to follow it down, but how? They could not blast a hole down there under water; but this idea occurred to them: They knew that rock-blasters drilled their powder holes 2 or 3 feet deep, and they concluded they could, with a longer and larger drill, bore a correspondingly deeper and larger hole. They fixed a long iron drill, with a 2½-inch chisel bit of steel, and attached the upper end to a spring pole with a rope. In this way the boring went on slowly and tediously, till on the 1st of November, 1807, at 17 feet in the rock, a cavity or fissure was struck, which gave an increased flow of stronger brine. This gave new encouragement to bore still further; and so, by welding increasing length of shaft to the drill from time to time, the hole was carried down to 28 feet, where a still larger and stronger supply of salt water was gotten.

Having now sufficient salt water to justify it, they decided and commenced to build a salt furnace, but, while building, continued the boring, and on the 15th January, 1808, at 40 feet in the rock and 58 feet from the top of the gum, were rewarded by an ample flow of strong brine for their furnace, and ceased boring.

Now was presented another difficulty: how to get the stronger brine from the bottom of the well, undiluted by the weaker brines and fresh water from above. There was no precedent here; they had to invent, contrive, and construct anew. A metal tube would naturally suggest itself to them; but there were neither metal tubes, nor sheet metal, nor metal workers, save a home-made blacksmith, in all this region, and to bore a wooden tube 40 feet long, and small enough in external diameter to go in the 2½-inch hole, was impracticable. What they did do was to whittle out of two long strips of wood two long half tubes of the proper size, and, fitting the edges carefully together, wrap the whole from end to end with small twine. This, with a bag of wrapping near the lower end, to fit as nearly as practicable, water tight, in the 2½-inch hole, was cautiously pressed down to its place, and found to answer the purpose perfectly, the brine flowed up freely through the tube into the gum, which was now provided with a water-tight floor or bottom to hold it, and from which it was raised by the simple swape and bucket.

a P. T., 1823; A. C. et P. (2), xxv, 178.

b P. M. (2), i, 402.

c A. C. et P. (2), 1, 78.

d *Journal of an Embassy to the Court of Ava*, 1834.

e *Constitution of Bitumens*, P. J. (2), ix, 487.

Thus was bored and tubed, rigged and worked, the first rock-bored salt-well west of the Alleghanies, if not in the United States. The wonder is not that it required eighteen months or more to prepare, bore, and complete this well for use, but, rather, that it was accomplished at all under the circumstances. In these times, when such a work can be accomplished in as many days as it then required months, it is difficult to appreciate the difficulties, doubts, delays, and general troubles that then beset them. Without preliminary study, previous experience, or training, without precedents in what they undertook, in a newly settled country, without steam-power, machine-shops, skilled mechanics, suitable tools or materials, failure rather than success might reasonably have been predicted. * * *

For interesting facts in this history of the boring of the first well I am indebted to a MS. by the late Dr. Henry Ruffner, and for personal recollections and traditions I am indebted to General Lewis Ruffner, Isaac Ruffner, W. D. Shrewsberry, Colonel B. H. Smith, Colonel L. I. Woodyard, W. C. Brooks, and others, and my own experiences for the last thirty years. * * *

Other important improvements were gradually made in the manner of boring, tubing, and pumping wells, etc. The first progress made in tubing, after Ruffner's compound wood-and-wrapping-twine tube, was made by a tinner who had located in Charleston. * * * He made tin tubes in convenient lengths, and soldered them together as they were put down the well. The refinement of screw joints had not yet come, but followed shortly after, in connection with copper pipes, which soon took the place of tin, and these are recently giving place to iron.

In the manner of bagging the wells, that is, in forming a water-tight joint around the tube to shut off the weaker waters above from the stronger below, a simple arrangement, called a "seed-bag", was fallen upon, which proved very effective, and which has survived to this day, and has been adopted wherever deep boring is done as one of the standard appliances for the purpose for which it is used. This seed-bag is made of buckskin or soft calfskin, sewed up like the sleeve of a coat or leg of a stocking, made 12 to 15 inches long, about the size of the well hole, and open at both ends; this is slipped over the tube and one end securely wrapped over knots placed on the tube to prevent slipping. Some six or eight inches of the bag is then filled with flaxseed, either alone or mixed with powdered gum tragacanth; the other end of the bag is then wrapped like the first, and the tube is ready for the well. When to their place—and they are put down any depth to hundreds of feet—the seed and gum soon swell from the water they absorb, till a close fit and water-tight joint are made. * * *

In 1831 William Morris, or "Billy" Morris, as he was familiarly called, a very ingenious and successful practical well-borer, invented a simple tool, which has done more to render deep boring practicable, simple, and cheap than anything else since the introduction of steam.

This tool has always been called here "slips", but in the oil regions they have given it the name of "jars". It is a long double-link, with jaws that fit closely, but slide loosely up and down. They are made of the best steel, are about 30 inches long, and fitted, top and bottom, with pin and socket joint, respectively. For use they are interposed between the heavy iron sinker, with its cutting chisel-bit below, and the line of auger poles above. Its object is to let the heavy sinker and bit have a clear, quick, cutting fall, unobstructed and unimpeded by the slower motion of the long line of auger poles above. In the case of fast auger or other tools in the well, they are also used to give heavy jars upward or downward, or both, to loosen them. From this use the oil-well people have given them the name of "jars".

Billy Morris never patented his invention, and never asked for nor made a dollar out of it; but as a public benefactor he deserves to rank with the inventors of the sewing-machine, reaping-machine, planing-machine, printing cylinders, cotton-gin, etc. This tool has been adopted into general use wherever deep boring is done, but outside of Kanawha few have heard of Billy Morris, or know where the slips or jars came from. * * *

The Kanawha borings have educated and sent forth a set of skillful well-borers all over the country, who have bored for water for irrigation on the western plains, for artesian wells for city, factory, or private use, for salt water at various places, for oil all over the country, for geological or mineralogical explorations, etc.

Nearly all the Kanawha salt-wells have contained more or less petroleum, and some of the deepest wells a considerable flow. Many persons now think, trusting to their recollections, that some of the wells afforded as much as 25 to 50 barrels per day. This was allowed to flow over from the top of the salt cisterns to the river, where, from its specific gravity, it spread over a large surface, and by its beautiful iridescent hues and not very savory odor could be traced for many miles down the stream. It was from this that the river received the nickname of "Old Greasy", by which it was for a long time familiarly known by Kanawha boatmen and others.

At that time this oil not only had no value, but was considered a great nuisance, and every effort was made to tube it out and get rid of it. It is now the opinion of some competent geologists, as well as of practical oil men, that very deep borings, say 2,500 feet, would penetrate rich oil-bearing strata, and possibly inexhaustible supplies of gas.

In Ohio salt was manufactured at the "Old Scioto salt works", in Jackson county, as early as 1798, from brine obtained from dug wells. In 1808, after the successful boring of the Ruffner well on the Kanawha, bored wells were substituted for dug wells very successfully, and salt-wells were soon in operation in other localities. The valley of the Muskingum from Zanesville to Marietta soon became noted, and the valley of Duck creek, since the center of the Washington county petroleum fields, was first famous for its salt-wells.

The following description is from an article in the *American Journal of Science* (1), xxiv, 63, by Dr. S. P. Hildreth, of Marietta:

Since the first settlement of the regions west of the Appalachian range the hunters and pioneers have been acquainted with this oil. Rising in a hidden and mysterious manner from the bowels of the earth, it soon arrested their attention, and acquired great value in the eyes of these simple sons of the forest. Like some miraculous gift from heaven, it was thought to be a sovereign remedy for nearly all the diseases common to those primeval days, and from its success in rheumatism, burns, coughs, sprains, etc., was justly entitled to all its celebrity. It acquired its name of Seneca oil, that by which it is generally known, from having first been found in the vicinity of Seneca lake, New York. From its being found in limited quantities, and its great and extensive demand, a small vial of it would sell for 40 or 50 cents. It is at this time in general use among the inhabitants of the country for saddle bruises and that complaint called the scratches in horses. It seems to be peculiarly adapted to the flesh of horses, and cures many of their ailments with wonderful certainty and celerity. Flies and other insects have a natural antipathy to its effluvia, and it is used with much effect in preventing the deposit of eggs by the "blowing fly" in the wounds of domestic animals during the summer months. In neighborhoods where it is abundant it is burned in lamps in place of spermaceti oil, affording a brilliant light, but filling the room with its own peculiar odor. By filtering it through charcoal, much of this empyreumatic smell is destroyed and the oil greatly improved in quality and appearance. It is also well adapted to prevent friction in machinery, for, being free of gluten, so common to animal and vegetable oils, it preserves the parts to which it is applied for a long time in free motion; where a heavy vertical shaft runs in a socket, it is preferable to all or any other articles. This oil rises in greater or less abundance in most of the salt-wells of the Kanawha, and, collecting as it rises, in the head on the water, is removed from time to time with a ladle.

On the Muskingum river the wells afford but little oil, and that only during the time the process of boring is going on; it ceases soon after the wells are completed, and yet all of them abound more or less in gas. A well on Duck creek, about 30 miles north of Marietta, owned by Mr. McKee, furnishes the greatest quantity of any in this region. It was dug in the year 1814, and is 475 feet in depth.

The rocks passed were similar to those on the Muskingum river above the flint stratum, or like those between the flint and salt deposit at McConnellsville. A bed of coal 2 yards in thickness was found at the depth of 100 feet, and gas at 144 feet, or 41 feet above the salt-rock. The hills are sandstone based on lime, 150 or 200 feet in height, with abundant beds of stone-coal near their feet. The oil from this well is discharged periodically at intervals of from two to four days, and from three to six hours duration at each period. Great quantities of gas accompany the discharges of oil, which for the first few years amounted to from 30 to 60 gallons at each eruption. The discharges at this time are less frequent, and diminished in quantity, affording only about a barrel per week, which is worth at the well from 50 to 75 cents a gallon. A few years ago, when the oil was most abundant, a large quantity had been collected in a cistern holding 30 or 40 barrels. At night, some one engaged about the works approached the well-head with a lighted candle. The gas instantly became ignited and communicated the flame to the contents of the cistern, which, giving way, suffered the oil to be discharged down a short declivity into the creek, whose waters pass with a rapid current close to the well. The oil still continued to burn most furiously; and, spreading itself along the surface of the stream for half a mile in extent, shot its flames to the tops of the highest trees, exhibiting the * * * spectacle of a river actually on fire.

It is probable that wells were drilled for salt in the neighborhood of Tarentum, on the Allegheny river, above Pittsburgh, about 1810. These wells were all comparatively shallow, but in many of them small quantities of petroleum often interfered more or less with their successful operation.

Salt-wells were bored along the Big Sandy river and its tributaries across Kentucky and into Tennessee, and in many of them petroleum appeared in sufficient quantity to be troublesome. In 1818 or 1819 a well was bored on the south fork of the Cumberland river, in Wayne county, Kentucky, that produced petroleum in such quantities that it was abandoned for brine and was almost forgotten for more than thirty years. This well has acquired some notoriety under the name of the Beatty well, and is still yielding small quantities of oil. Farther west, in Barren and Cumberland counties, Kentucky, along the Cumberland river and its tributaries, numerous salt-wells were bored, and in many of them petroleum appeared. In 1829 the famous American well was bored near the bed of Little Rennox creek, near Burkesville, Kentucky. The following account of the phenomena attending its completion is to be found in *Niles' Register* (3), xiii, 4:

Some months since, in the act of boring for salt water on the land of Mr. Lemuel Stockton, situated in the county of Cumberland, Kentucky, a vein of pure oil was struck, from which it is almost incredible what quantities of the substance issued. The discharges were by floods, at intervals of from two to five minutes, at each flow vomiting forth many barrels of pure oil. I witnessed myself, on a shaft that stood upright by the aperture in the rock from which it issued, marks of oil 25 or 30 feet perpendicularly above the rock. These floods continued for three or four weeks, when they subsided to a constant stream, affording many thousand gallons per day. This well is between a quarter and a half mile from the bank of the Cumberland river, on a small rill (creek), down which it runs to the Cumberland river. It was traced as far down the Cumberland as Gallatin, in Sumner county, Tennessee, nearly 100 miles. For many miles it covered the whole surface of the river, and its marks are now found on the rocks on each bank. About 2 miles below the point on which it touched the river it was set on fire by a boy, and the effect was grand beyond description. An old gentleman who witnessed it says he has seen several cities on fire, but that he never beheld anything like the flames which rose from the bosom of the Cumberland to touch the very clouds.

Referring to this article and the well, a correspondent of the *Burkesville Courier*, C. L. S. Mathews, esq., under date October 11, 1876, says:

This well, from the long continued yield of oil, is one of the most remarkable wells in America. When first struck, oil flowed from it at the rate of 1,000 barrels per day, and for many years, in fact, until the year 1860, it yielded a plentiful supply of oil. We have been informed by several old citizens, who witnessed the burning of the oil on the surface of the river, that the oil burned down the river about 56 miles, and that for miles all the vegetation and foliage along the river bank was destroyed. Some years after this strike was made several individuals took charge of the well, saved the oil, and put up several hundred thousand bottles, which they sold all through this country and some parts of Europe as the "American Medicinal Oil, Burkesville, Kentucky".

During the decade from 1830 to 1840 the attention of the most distinguished French chemists was directed to the investigation of bitumens. Boussingault continued his general researches, and in 1837 published a classical paper on the subject. (a) Virlet d'Oust propounded the first theory regarding the origin of bitumens in 1834, (b) and the asphalt of the Dead sea, (c) of Pymont, (d) and near Havana, Cuba, were examined. (e) Hess wrote on the products of dry distillation (f) and was reviewed by Reichenbach, (g) who, with Laurent, (h) continued his researches upon paraffine. In 1833 Professor Benjamin Silliman, sr., contributed an article to the *American Journal of Science* (1), xxiii, 97, in which he describes the celebrated oil-spring of the Seneca Indians near Cuba, New York, as follows:

The oil-spring, or fountain, rises in the midst of a marshy ground; it is a muddy and dirty pool of about 18 feet in diameter, and is nearly circular in form. There is no outlet above ground, no stream flowing from it, and it is, of course, a stagnant water, with no other circulation than that which springs from changes of temperature and from the gas and petroleum which are constantly rising through the pool.

We are told that the odor of petroleum is perceived at a distance in approaching the spring. This may not improbably be true in particular states of the wind, but we did not distinguish any peculiar smell until we arrived on the edge of the fountain. Here its

a A. C. et P. (2), lxiv, 141.

b B. S. G. F. (1), iv, 372.

c *Journal des Savants*, 1855, 596.

d Rozet, B. S. G. F. (1), vii, 138.

e Taylor & Clemson, P. M., x, 161.

f *Pog. An.*, xxxvi, 417, xxxvii, 534.

g *Jour. für Ökonom. Chem.*, viii, 445.

h Laurent, A. C. et P. (2), liv, 392, lxiv, 321.

peculiar character becomes very obvious. The water is covered with a thin layer of petroleum or mineral oil, giving it a foul appearance, as if coated with dirty molasses, having a yellowish-brown color. Every part of the water was covered by this film, but it had nowhere the iridescence which I recollect to have observed at Saint Catharine's well, a petroleum fountain near Edinburgh, in Scotland. There the water was pellucid, and the lines produced by the oil were brilliant, giving the whole a beautiful appearance. The difference is, however, easily accounted for. Saint Catharine's well is a lively, flowing fountain, and the quantity of petroleum is only sufficient to cover it partially, while there is nothing to soil the stream; and in the present instance the stagnation of the water, the comparative abundance of the petroleum, and the mixture of leaves and sticks and other productions of a dense forest, preclude any beautiful features. There are, however, upon this water, here and there, spots of what seems to be a purer petroleum, probably recently risen, which is free from mixture, and which has a bright, brownish-yellow appearance, lively and sparkling; and were the fountain covered entirely with this purer production it would be beautiful.

They collect the petroleum by skimming it, like cream from a milk-pan. For this purpose they use a broad, flat board, made thin at one edge like a knife; it is moved flat upon and just under the surface of the water, and is soon covered by a coating of the petroleum, which is so thick and adhesive that it does not fall off, but is removed by scraping the instrument upon the lip of a cup. It has then a very foul appearance, like very dirty tar or molasses, but it is purified by heating and straining it while hot through flannel or other woolen stuff. It is used by the people of the vicinity for sprains and rheumatism and for sores on their horses, it being in both cases rubbed upon the part. It is not monopolized by any one, but is carried away freely by all who care to collect it, and for this purpose the spring is frequently visited. I could not ascertain how much is annually obtained; the quantity must be considerable. It is said to rise more abundantly in hot weather than in cold.

I cannot learn that any considerable part of the large quantities of petroleum used in the eastern states under the name of Seneca oil comes from the spring now described. I am assured that its source is about 100 miles from Pittsburgh, on Oil creek, which empties into the Allegheny river in the township and county of Venango. It exists there in great abundance, and rises in purity to the surface of the water; by dams, inclosing certain parts of the river or creek, it is prevented from flowing away, and it is absorbed by the blankets, from which it is wrung.

The petroleum sold in the eastern states under the name of Seneca oil is of a dark brown color, between that of tar and molasses, and its degree of consistence is not dissimilar, according to the temperature; its odor is strong and too well known to need description.

In an article entitled "Observations on the bituminous coal deposits of the valley of the Ohio" Dr. S. P. Hildreth, in 1836, notices the occurrence of petroleum on the Little Kanawha. (*a*)

The decade from 1840 to 1850 was remarkable for the number of travelers who, in different parts of the world, noticed the occurrence of bitumen, and also for several elaborate researches upon the geological occurrence and chemical constitution of its different varieties. Travelers visited the far east, and even China, (*b*) and gave glowing descriptions of the naphtha springs of Persia, (*c*) the fire-worshippers of Baku, and the fire wells of China. (*d*) The naphtha springs of Persia are nowhere else described in such detail as in Ritter's *Erdkunde*, published in 1841. (*e*) Boussingault (*f*) continued his researches in France, and in our own country, Percival, (*g*) in Connecticut, and Beck, (*h*) in New York, called attention to the fact that bitumen was of frequent occurrence in thin veins traversing the metamorphic and eruptive rocks of Connecticut, New York, and New Jersey. In 1842 E. W. Binney first called attention to the occurrence of petroleum in the Down Holland Moss, which may be said to have been the first step toward the great paraffine oil industry of Scotland. (*i*)

SECTION 3.—THE RISE OF THE PARAFFINE-OIL INDUSTRY.

This decade witnessed the rise of the paraffine-oil industry in Europe and the United States. The success of the manufacture of shale oil at Bathgate, Scotland, by E. W. Binney & Co., from so-called Boghead coal, has been more popularly known through Mr. James Young, one of Mr. Binney's associates. The lessening supply of sperm and whale oils, and their consequent advance in price, led to various attempts to invent or discover a cheaper substitute, and as a consequence the oils manufactured at Bathgate were eagerly sought in the market, especially when lamps were formed that would burn them with complete success. Mr. Binney claims to have first called these oils paraffine oils, but those used for illumination have been more widely known as kerosene. (*j*)

In the United States experiments were commenced in the winter of 1850-'51 by Luther and William Atwood near Boston, which resulted in the establishment in 1853 of the United States Chemical Manufacturing Company at Waltham, Massachusetts. This company manufactured from coal-tar an oil called "Coup oil", which was used, mixed with cheap animal and vegetable oils, for lubricating machinery. In 1854 Mr. Joshua Merrill became connected with this company, but in 1855 he left it and became connected with the Downer Kerosene Oil Company of Boston, with which he has remained to the present time. These three gentlemen were the pioneers in the manufacture of paraffine oils in the United States. In 1857 the Downer Kerosene Oil Company commenced the manufacture of hydrocarbon oils from the Albert coal (a kind of asphaltum), obtained from New Brunswick, and they had works in Boston, Massachusetts, and in Portland, Maine. William Atwood had charge of the works in

a A. J. S. (1), xxix, 121.

b Pottinger; W. Robinson; Ainsworth.

c Kinnier: *Persia*.

d Humboldt: *Asie Centrale*, ii, 519; *Cosmos*, I, 232; Bohn I, 221.

e *Die Erdkunde von Asien*, vols. vii, viii, ix, x, and xi.

f A. C. et P. (2), lxxiii, 442.

g A. J. S. (3), xvi, 130.

h A. J. S. (1), xlv, 335.

i Papers read before the Manchester (England) Geological Society, 1842-'43.

j Communication from Mr. Binney to S. F. P.

NOTE.—The claims of Selligue as the original inventor of paraffine oils distilled from shale are stated elsewhere. I think the paraffine-oil industry took its rise at this time.

Portland, Joshua Merrill of those in Boston, and Luther Atwood of a large establishment belonging to the New York Kerosene Oil Company near Brooklyn, Long Island. Before these gentlemen left Waltham they had "experimented upon bituminous coals, bituminous shales, asphaltum, and petroleums—petroleums and bitumens from nearly all the known sources, and many different varieties of coals and shales. They succeeded in producing what they regarded at that time as a good lubricating oil from each of those sources". (a)

Previous to going to Portland Mr. William Atwood spent about eighteen months on the island of Trinidad attempting to produce crude lubricating oils from the asphalt of the celebrated Pitch lake.

Meantime, parties in New Bedford, Massachusetts, who had been engaged in the manufacture of whale and sperm oils, commenced the manufacture of paraffine oils from the Boghead mineral of Scotland, which they imported for that purpose. The rich cannel coals of West Virginia and Kentucky soon attracted attention, and works for the manufacture of paraffine oils from them were established at Cloverport, Kentucky, and at Newark, Ohio. On the Allegheny river, in Westmoreland county, Pennsylvania, the Lucesco works were the largest in the country in 1859, having a capacity for producing 6,000 gallons of crude oil per diem. At Canfield, Mahoning county, Ohio, was another, and at Cannelton, West Virginia, was another with refining works at Maysville, Kentucky. By 1859 Luther Atwood had introduced his method of downward distillation, in which a tower was filled with 25 tons of coal or Boghead mineral and a fire kindled on the upper surface by means of anthracite coal or pine wood. (b) A downward draft was created by a steam-jet in the pipe leading from the base of the tower, and the heated products of combustion, descending through the coal, expelled the volatile materials at the lowest possible temperature.

In a recent letter, Mr. E. W. Binney, of Manchester, England, who, as before stated, was associated with Mr. James Young, at Bathgate, Scotland, tells me that when Mr. Young, in his celebrated patent lawsuit, testified that he obtained paraffine oil from petroleum before he resorted to coal, and it became known on this side of the Atlantic, the American firms licensed under their patent refused to pay any more royalties and went to work manufacturing petroleum. This is doubtless true as a statement of fact, but it conveys a wrong impression. The fact is that an inadequate supply alone prevented the use of petroleum in this country prior to 1859, and really Mr. Young and those on this side of the Atlantic were then in precisely the same situation as regards petroleum; but at the end of 1859 the situation in America became revolutionized, while that in Scotland remained as before.

SECTION 4.—HISTORICAL NOTICE FROM 1850 TO THE COMPLETION OF DRAKE'S WELL (AUGUST, 1859).

While Mr. Everett was engaged in making oil from cannel coal at Canfield, Ohio, Dr. J. S. Newberry sent him some petroleum from Mecca, Ohio, which was pronounced "as good or better than crude oil from coal". Oil had been gathered along Mill creek, in Erie, Pennsylvania, since 1854, and had been sold to druggists for a dollar a gallon. At Oxbow hill, not far from Union City, Erie county, Pennsylvania, Mr. P. G. Stranahan and his brothers dug out a spring about 1845 from which oil has flowed ever since.

William C. and Charles Hyde were engaged in lumbering on Oil creek, near the present village of Hydetown, from 1845 to 1850. The former, being well acquainted at that time with the oil-springs near Titusville, went to Pittsburgh and inquired of R. Robinson & Co., grocers, for a cheap oil for lighting mills, and got a half-barrel of amber oil, called "rock-oil", which was used in a vessel resembling a tea-kettle, the wick projecting from the nozzle, and burned much better than the green oil of Oil creek. The latter had long been collected from curbed pits, in which the oil arose and floated upon the water. Blankets were spread upon the water, which absorbed the oil, which was then wrung from them. Mr. J. D. Angier contrived a series of pits, one above another, and allowed the water to flow out from beneath the oil, and in this way he obtained what was then considered a large amount—six gallons a day.

From 1845 to 1855 parties were actively engaged in manufacturing salt at Tarentum, on the Allegheny river, above Pittsburgh, among them a Mr. Kier, whose son, Samuel M. Kier, was a druggist in Pittsburgh. Mr. Kier bored a well for brine at Tarentum and obtained oil that looked like brandy with the water, and this was allowed to flow into the canal leading to Pittsburgh. Mr. Samuel M. Kier's wife was sick, as was supposed, with consumption, and her physician prescribed "American oil". It helped her, and her husband was led to compare it with that obtained from his father's well. Concluding, as they possessed the same odor, that they were the same thing, he submitted them to a chemist, who pronounced them identical. Mr. S. M. Kier soon after commenced to bottle American oil for sale, and after a few years, supposed to be about 1855, in company with Mr. McKuen, he first refined petroleum from his father's wells at Tarentum. The oils were treated like the crude oils obtained from coal, and were made into burning oils and heavier oils, that were sold to the woolen factory at Cooperstown for cleansing wool, for which they were found very valuable. This refinery created a demand for crude petroleum, and led people to reflect upon the possibility of procuring it in larger quantity.

While Kier was at work in Pittsburgh, the firm of Brewer & Watson were engaged in a large lumbering and general merchandise business at Titusville, on Oil creek. In the summer of 1854 Dr. F. B. Brewer, whose

a Testimony of William Atwood in case of Merrill vs. Youmans.

b Antisell, page 135.

father was at the head of this firm, visited relatives at Hanover, New Hampshire, and carried a bottle of petroleum to Professor Crosby, of Dartmouth College, of which institution the doctor was a graduate, and Mr. A. H. Crosby, a son of the professor, and now a physician in Concord, New Hampshire, became greatly interested in his representations respecting the petroleum and the oil-springs. At this time Mr. George H. Bissell, also a native of Hanover, and a graduate of Dartmouth, was on a visit to his old home, and was induced by the others to join an enterprise for forming a stock company for procuring petroleum on Oil creek. Mr. Bissell was then engaged in the practice of law in New York as a member of the firm of Eveleth & Bissell. After some time spent in negotiation, during which Dr. Crosby had visited Oil creek and advised boring as a means of obtaining the oil in larger quantities, an arrangement was effected with Messrs. Brewer & Watson, under which Messrs. Eveleth & Bissell proceeded to organize a company.

Under date of November 6, 1854, these gentlemen informed Dr. Brewer that they "had forwarded several gallons of the oil to Mr. Atwood, of Boston, an eminent chemist, and his report of the qualities of the oil and the uses to which it may be applied was very favorable. Professor Silliman, of Yale College, is giving it a thorough analysis, and he informs us that, so far as he has yet tested it, he is of opinion that it contains a large proportion of benzole and naphtha, and that it will be found more valuable for purposes of application to the arts than as a medicinal, burning, or lubricating fluid".

The first deed from Brewer, Watson & Co. was dated November 10, 1854, and conveyed to George H. Bissell and Jonathan G. Eveleth, of New York city, 105 acres of land on what was known as the "Watson flats", embracing the island at the junction of Pine and Oil creeks. It was on this island that Mr. Angier's pits were dug, and also where the first well was drilled five years later.

As a result of this purchase, the Pennsylvania Rock Oil Company was incorporated on the 30th of December, 1854, under the laws of the state of New York. In order to satisfy several residents of New Haven who took an interest in the enterprise in consequence of Professor Silliman's report, which was made in April, 1855, the property of the company was purchased by Messrs. Ives & Pierpont, and was leased by them to a new company bearing the same title and organized under the laws of Connecticut, the official residence of the company being transferred to the city of New Haven. By the 23d of March, 1857, the Pennsylvania Rock Oil Company had leased the property on Oil creek to the New Haven stockholders, who organized under the name of "The Seneca Oil Company", and E. L. Drake was engaged the following spring to go out to Titusville and drill an artesian well for oil.

Mr. Drake, called Colonel Drake on Oil creek, arrived in Titusville about May 1, 1858. At that time Titusville was a lumbering village, and the nearest point at which tools and machinery could be obtained was Erie, Pennsylvania, nearly 100 miles north, or Pittsburgh, still farther south. Drake commenced operations by attempting to sink a shaft in one of the old timbered pits once supposed to be of prehistoric origin, but hatchets of French manufacture have been discovered in or about these pits. His idea appears to have been at first to sink a shaft or ordinary well by digging; but water and quicksands continually thwarted him, and he finally resorted to the expedient of driving an iron pipe from the surface to the solid rock. This device is supposed to have been original with Drake; but if it was, he never attempted to reap any advantage from it, although it has been of great value ever since in artesian boring.

He appears to have prepared for boring during the season of 1858 by driving his pipe 36 feet to the rock and getting his engine, tools, and pump-house in order; but the men he had engaged to drill early in the season had secured another job, and the work was suspended until the following season, when Mr. William Smith and his two sons were engaged, they having had large experience on salt-wells. These men arrived at Titusville about the middle of June, bringing with them all the necessary tools for drilling. After many vexatious delays, they were fairly under way by the middle of August and had drilled 33 feet, when, on the 28th of August, 1859, the drill struck a crevice, into which it fell six inches. The following day being Sunday, Smith visited the well in the afternoon and found the drill-hole full to within a few feet of the top, and on fishing up a small quantity in a tin cup it was found to be petroleum. Such is the story of the first petroleum well. (a)

As soon as Mr. Watson heard the news he sprang upon a horse and hastened down Oil creek to lease the farm on which the McClintock spring was situated; but Drake telegraphed to Mr. Bissell, who thereupon bought up all the stock of the Pennsylvania Rock Oil Company that he could get hold of, and, immediately visiting Oil creek, leased large tracts of land that afterward yielded abundantly.

SECTION 5.—HISTORICAL NOTICE OF THE PETROLEUM INDUSTRY IN THE UNITED STATES SINCE THE COMPLETION OF DRAKE'S WELL (AUGUST, 1859).

The territory over which operations were conducted was for a long time confined to the valleys of the Allegheny river and its tributaries, on the supposition that the present configuration of surface was related to the strata containing the oil. For this reason wells were drilled in the valley of Oil creek from Titusville to Oil City, on French creek from Union City to Meadville and Franklin, and on the Allegheny at Tidionte. Although the coal-oil manufactories all over the country, with scarcely an exception, commenced to work petroleum instead of

^a I am indebted to Henry's *Early and Later History of Petroleum*, which is indorsed by Mr. Bissell, and to many conversations with residents of Titusville and the vicinity, for the facts contained in the above narration.

coal, the production was so enormous, as compared with the demand, that the market was soon glutted and the price fell to almost nothing. An extended demand, and the partial exhaustion of the territory then being worked, led to better prices in 1865, and the immediate result was the boring of wells over an immense extent of country, from Manitoulin island to Alabama, and from Missouri to central New York. In Europe companies were also formed, and wells were put down wherever an oil-spring existed. In the United States the result was the permanent development of a small territory in southern Kentucky, another still larger in West Virginia and in Washington county, Ohio, and another in Trumbull county, Ohio, at Mecca. In Pennsylvania oil was found at Smith's Ferry, on the Ohio river, in Beaver county, and the hill region lying in the angle formed by Oil creek and the Allegheny river from Tidioute across to Titusville was explored and several localities of great richness were opened up.

Henry, in *Early and Later History of Petroleum*, pages 109 and 110, says:

The total daily product of all the wells in June, 1860, was estimated at 200 barrels. By September, 1861, the daily production had reached 700 barrels, and then commenced the flowing-well period, with an addition to the production of 6,000 or 7,000 barrels a day. The price fell to 20 cents a barrel, then to 15, and then to 10. Soon it was impossible to obtain barrels on any terms, for all the coopers in the surrounding country could not make them as fast as the Empire well could fill them. Small producing wells were forced to cease operations, and scores of operators became disheartened and abandoned their wells. The production during the early part of 1863 was scarcely half that of the beginning of 1862, and that of 1864 was still less. In May, 1865, the production had declined to less than 4,000 barrels per day.

Commencing at Titusville in 1859, the tide of development swept over the valley of Oil creek and along the Allegheny river above and below Oil City for a considerable distance; then Cherry run, in 1864. Then came Pithole creek, Benninghoff and Pioneer run; the Woods and Stevenson farms, on Oil creek, in like succession, in 1865 and 1866; Tidioute and Triumph hill in 1867, and in the latter part of the same year came Shamburg. In 1868 the Pleasantville oil-field furnished the chief center of excitement.

While this great activity was being displayed in Pennsylvania, the old salt and petroleum region in the valley of the Muskingum, in Ohio, and on the Little Kanawha, in West Virginia, was bored for petroleum, and several wells of great productiveness were obtained. In 1860 an old brine well at Burning Springs, West Virginia, that had yielded petroleum, was cleaned out, the water tubed off, and about fifty barrels of oil per day secured. In the following winter the Llewellyn well was struck at about the depth of 100 feet, and it flowed over 1,000 barrels a day. Several other good wells were secured, when, during a confederate raid, the property was destroyed and the operators were driven away. In 1864 operations were resumed, deeper wells producing a large amount of oil, and speculation and excitement ran to a high pitch. In 1865 operations were successfully undertaken at White Oak, which resulted in developing the most extensive and best known West Virginia territory. From 1860 to 1865 wells were successfully drilled on Cow run and at other localities in Washington county, Ohio.

For more than a century bitumen had been known in southern California between Santa Barbara and Los Angeles, and had also been observed floating upon the sea in the Santa Barbara channel between the islands and the mainland. Early in 1864 this region was visited by an eminent eastern chemist, who was so far misled by false local representations and by gross deceptions practiced upon him as to induce him to make a report upon this as a petroleum-producing region of great richness. This report, and others of a similar character, led to the formation of mining companies representing stock to the value of millions of dollars, all of which, it is needless to add, was lost to the *bona fide* investors. Several hundred thousand dollars were spent in boring wells, but few of them produced sufficient petroleum even to serve as a specimen, and none, so far as I am informed, paid the cost of boring. A few years of effort found the companies with depleted treasuries and no oil, and with a large amount of land and apparatus on their hands. On one estate 5,000 barrels in shooks, shipped from New York, were rotting down in a huge pile before a drop of petroleum had been obtained from beneath its surface. While these magnificent enterprises were becoming magnificent failures, more humble efforts were achieving a measure of success in driving tunnels into the steep mountain sides upon the petroleum-bearing rock. The total production of this region, however, never reached above a few thousand barrels of inferior quality per year, and the San Francisco market continued to be supplied almost exclusively with Pennsylvania petroleum shipped around cape Horn. (a)

From 1870 to 1880 the region between Tidioute and Oil creek has constantly become relatively of less importance when compared with the entire area of producing territory in Pennsylvania. At the beginning of this decade the production of this region had considerably lessened, and a number of new and very successful wells farther down the Allegheny river were attracting attention in that direction. Wells had been put down near the junction of the Clarion and Allegheny rivers as early as 1863 and 1864, but very little notice had been taken of them at the time; and it was not until 1868 that a successful well on the hill above Parker's landing attracted the attention of the bolder operators and led to the development of what is termed the "lower country", lying in Butler, Armstrong, and Clarion counties. In 1867 Mr. O. D. Angell had developed a very productive oil property on Belle island, in the Allegheny river, 25 miles below Oil City. While carrying forward his work he was busily investigating the occurrence of petroleum by studying the relative position of the most productive wells. He had observed in the "upper country" that a narrow belt extending across from Scrubgrass, on the Allegheny river, to Petroleum Center, on Oil creek, included many of the best wells in that region. In the "lower country" he

a Advices from the Pacific coast indicate that during the years 1880 and 1881 a petroleum interest that promises some local value has been developed in a portion of the state further north than that here referred to.

projected a similar belt, lying in a direction nearly parallel with the first, and extending from Saint Petersburg, in Clarion county, through Parker's landing, to Bear creek, in Butler county. A glance at the map (III) accompanying this report will show how Angell's so-called "belt theory" corresponded to the facts as shown by subsequent developments. As is usually the case, the majority of operators scoffed, while a few listened, and, after listening, went to work. The results have shown that the oil rock lies in belts or in long and narrow areas, having a general northeast and southwest extension, often not more than 30 rods in width, but several miles in length; that the sand rock is thickest and most productive along the axis of the belt, thinning out toward its borders, the upper surface being level and the under surface curved upward from the center; that the present configuration of the surface has no relation to the form, extent, or direction of the "belt". These facts established, and their successful application abundantly demonstrated by the remarkable success attending Angell's operations, have given a certain degree of accuracy to the development of oil territory that it never possessed before. On the other hand, they have led to very exaggerated views, some enthusiasts affirming their belief that the line of north 16° east, upon which Angell achieved his first success, governed the direction and extent of territory containing oil from Canada to Tennessee. I shall again refer to the facts upon which Angell's theory is based in my chapter on the "Origin of Bitumens". (a)

Angell kept his own counsel at first, and obtained a sufficient number of leases on favorable terms to insure his financial success; but the plan upon which he worked became apparent from the character of his operations, and others followed, or attempted to follow, his example, and wells were drilled across the country to the southwest of Parker's landing into Butler county, and often miles in advance of any territory hitherto proved profitable, until a tract was more or less clearly outlined about five miles in breadth and thirty-five miles in length, the principal axis of which lay in the general direction north 22° east. Other less extended belts lying generally parallel to this will be noticed by glancing at the map (III).

During the early years of this decade, when Angell's efforts and sagacity were being rewarded in the lower country with success in a most substantial form, other operators struck out from the "upper country" of Oil creek in a general northeast direction, some on a line north 16° east, others north $22\frac{1}{2}^{\circ}$ east, and others on still other lines, often traced over the forest-covered hills of that region with a compass, and located their wells in the expectation of finding other sand-bars of the ancient sea from which the oil would rush to the surface. They finally reached the town of Bradford, in McKean county, a locality which some thought could never produce oil.

It was not the first attempt at well-drilling that obtained oil in the neighborhood of Bradford. In 1862 the old Bradford well, since known as the Barnsdall well, was drilled to a depth of 200 feet with a spring-pole and then abandoned. In 1866 the citizens of the village of Bradford concluded to club together and sink the Barnsdall well deeper, and it was drilled to a total depth of 875 feet, or to within 150 feet of the Bradford producing sand. In 1865 F. E. Dean and brothers drilled a well in the valley of Tuna creek, on the Shepherd farm, near the present site of Custer City, 160 feet of drive-pipe being used, and the hole being drilled to 900 feet, but it was abandoned when over 200 feet above the top of the oil-sand.

The next well was drilled by the Dean brothers on the Clark farm, at Tarport, and drilling was stopped at a depth of 605 feet, or over 400 feet above the top of the oil-sand. All of these wells were drilled with the expectation of finding the Venango county oil-sand at about the same depth below water-level as at Oil City, but they were all failures.

The first well sunk to the Bradford sand was drilled by Mr. James E. Butts and others, under the name of the Foster Oil Company, on the Gilbert farm, 2 miles northeast of Bradford. "Slush oil" was found at a depth of 751 feet, and in November, 1871, producing sand was struck at 1,110 feet. The daily production was 10 barrels, and from the time this well was struck to December, 1874, no wells were drilled to amount to anything. On December 6, 1874, Messrs. Butts and Foster struck the oil-sand on the Archy Buchanan farm, $2\frac{1}{2}$ miles northeast of Bradford. This well started off with a daily production of 70 barrels, and was really the first that attracted attention to the possibility of finding a profitable oil district in the county. In December, 1878, four years from the completion of the Butts well, the average daily production of crude oil was 23,700 barrels, or about four-sevenths of the total daily production of the state of Pennsylvania, while in December, 1880, two years later, and six years from the completion of the first well, out of a total average daily production for the Pennsylvania oil-fields of 72,214 barrels, 63,000 barrels were yielded by the Bradford field alone.

During the year 1879 there were 475 wells drilled to the Venango sands in the counties of Warren, Venango, Clarion, and Butler. Of this number 122 were dry holes, or produced no oil, being 25.7 per cent.

In the Bradford or northern district there were during the same year 2,536 wells drilled to the Bradford oil-sand, of which number but 76 were dry holes, or only 3 per cent., being nearly 23 per cent. less than in the Venango or western district.

The average daily production for the first month of the wells drilled in the Bradford sand was about 20 barrels, while for the wells in the Venango sands it did not attain that amount. Some of the wells drilled to the Venango third-oil sand have produced from 2,000 to 3,000 barrels of oil per day, while the largest well ever found in the

Bradford district has not exceeded as many hundred. The largest individual wells have been located in the western district; the largest average wells in the northern district. Since the beginning of the year 1875, when the Bradford oil horizon was discovered, there have been 6,249 wells drilled in the district, of which 236 were dry holes, or 3.77 per cent. From the most authentic statistics which I can gather in the western district, about one-fourth of the wells that have been drilled in the Venango sands, since their discovery in 1859, have proved dry. When we take these facts into consideration, we can readily understand why there should have been 2,536 wells drilled in the northern district to only 475 in the western in 1879. (*a*)

During 1880, as undrilled territory became more scarce in the Bradford field, what are termed "wild-cat" or test wells were drilled both to the northeast and to the southwest of Bradford, and the result has determined two areas, one near the city of Warren, and another around Stoneham, both in Warren county, Pennsylvania. To the northeast an area not yet outlined has been determined around Richburg, Cattaraugus county, New York.

Forty-five years ago M. C. Read, esq., now of Hudson, Ohio, lived in Mecca, on the east side of Mosquito creek. It had been observed for a long time that petroleum gushed out when stones were removed from their places along the bank of the creek, and as it frequently appeared in wells it was considered a nuisance. In the spring of 1860, when there was great excitement in eastern Ohio over the oil in Pennsylvania, Mr. Read mentioned to some persons what he knew about the oil-springs in Mecca, and it was only a few days thereafter before property was being leased in that place on a royalty of from one-tenth to one-quarter, and in a year all available property on the west side of the creek and some on the east side had been taken up.

Wells were bored rapidly, yielding from 10 to 20 barrels, and in some cases were so near together that one sucked air from the other when pumped. Thousands of barrels of oil were taken out yearly for a few years, when a large part of the wells became exhausted, many of them were abandoned, and the excitement subsided. In 1864 it was renewed for a short time, and Pennsylvania parties bought up all the land on the east side of the creek and obtained a few good wells, but they soon failed. Since that time a few persons have been engaged in drilling new wells and pumping the old ones, for the most part spending what they got on good wells in drilling others which produced nothing. In the opinion of those best qualified to judge, Mecca oil operations have netted nothing, or more probably have resulted in a loss. The operators now make a living, all money earned over and above being spent in putting down new wells.

Near Power's Corners there was in early times an old shaft which tradition credited as the work of a prehistoric race. Such an origin is not probable.

At Belden, in Lorain county, Ohio, it is reported that one Reuben Ingersoll sunk a well for salt in 1818 or 1819 on the Root farm, but so much oil came with the brine that the well was soon abandoned. The oil for a long time was skimmed off and sold as a medicine. Many years afterward, in sinking a hole for the post for a flood-gate to a mill, petroleum appeared at the bottom, and occasionally it appeared in other excavations.

It is claimed that the first well was bored here for oil in 1853, but on what authority I do not know. It is said to have been bored 500 feet deep by a Mr. Harper and to have struck oil at 50 feet. In 1860 a Mr. Gardener sunk Harper's well to 1,200 feet and abandoned it.

Other wells were put down soon after, and one of them—the old Crittenden well—in 1862 pumped by hand, wind-mill, and steam-power 65 barrels. A few wells at Liverpool have a similar history.

A Mr. Thoms in 1850 gathered oil from holes dug in the sand on a bar of the Ohio river near the mouth of Little Beaver creek, Beaver county. The first well was the Fenton well, drilled in 1860, close to the mouth of Dry run. This well was 170 feet deep, and yielded 14 or 15 barrels of heavy lubricating oil. They then went down along the river 575 feet and on Island run 600 feet, and reached a fine, close sand. Some wells were carried down 1,100 or 1,200 feet to the second sand, yielding a little oil. Wells in this section have never been drilled 1,500 to 1,600 feet to the third sand. This territory is between three and four miles square. Some oil has also been obtained at Beaver creek and Rochester, in the same county; but the principal development in this section is confined to a small territory immediately north of Smith's ferry, and has occurred since 1878.

SECTION 6.—HISTORICAL NOTICE OF THE RUSSIAN PETROLEUM INDUSTRY.

There are five foreign oil-fields that have attracted attention and that have produced more or less oil in commercially valuable quantities. They are the region of the Caucasus, Galicia, Canada, Japan, and Peru. Of these, the first mentioned is altogether the most important so far as present information indicates. Next may be placed Canada; but as regards the relative importance of the others it would be difficult to decide.

The Russian fields lie in two districts, one at either extremity of the Caucasus. The western, on the Black sea, is the Kouban, on a river of the same name; the eastern is the Baku district, on the peninsula of Apscheron, extending into the Caspian sea, and on which the city of Baku stands.

The Kouban district is situated on the northwestern slope of mount Oshten, which is the most western peak of the Caucasus, 9,000 feet in height. Its area is about 250 square miles. Operations were commenced here in 1864

a I am indebted for the major portion of this statement in reference to the Bradford field to two papers by Charles A. Ashburner, esq.—the first read at the Baltimore meeting of the American Institute of Mining Engineers, February, 1879; the second read before the American Philosophical Society, March 5, 1880. P. A. P. S., xviii, 419; T. A. I. M. E., 1879; P. A. P. S., 1880.

by the Russian colonel Novosiltsoff, who had a monopoly of the petroleum industry of that region for more than twelve years. He sunk his first well at Peklo, near the coast of the Black sea, and after many borings, with varying success, in different parts of the district, he became so heavily involved that to save him from bankruptcy the government placed the petroleum interests under a curatorship.

From these exploitations of varying depth, large quantities of excellent petroleum of specific gravity from 38° to 48° Baumé have been obtained.

The most remarkable well was obtained at Kandako in 1866. At a depth of only 40 feet from 10 to 12 barrels of oil per day were yielded. At a depth of 123½ feet the first flow of oil appeared and yielded 125 barrels of oil per day, throwing it 14 feet high. The well was mismanaged and choked, and when finally reopened and sunk to 182 feet, a flow of oil rose to 40 feet high, and gave 250 barrels per day. It was again choked and finally deepened to 242 feet, when the oil again flowed with great power and violence, yielding several thousand barrels per day, and continued its spontaneous action for eighteen months. (a)

This management came to an end in 1877, on the breaking out of the last Russo-Turkish war, when the whole district of the Kouban was abandoned. In 1879 the larger portion of the district, amounting to 1,500,000 acres, was leased to Dr. H. W. O. Tweddle, with private estates amounting to 90,000 acres additional. During the years 1879 and 1880 great activity has prevailed in preparation for an extensive development of oil with all of the appliances in use in Pennsylvania for obtaining, handling, and refining petroleum.

Concerning the history of petroleum production at Baku, Consul Dyer wrote, on August 10, 1880, as follows:

From time immemorial oil has been known to exist at Baku, and for generations the natives have taken it for greasing their vehicles, preparing skins for wine, etc., and for use in the southern countries for embalming the dead, and even in some cases for illuminating purposes. Their wants were, however, small, and the surface production was sufficient.

The wells were rather receptacles for the surface oil than otherwise, as they were simply holes dug a few feet deep in the earth.

From the time of the Russian occupation of the country in 1723 down to 1825 this industry remained almost neglected. From 1813 something was done, but nothing of importance, and the total revenue to the government arising from it was less than \$40,000 per year. From time to time private persons took the privilege, and at times the crown worked them to some extent. The price charged for the oil was as high as 4 rubles per pood, and thus the industry was destroyed. (b)

It was about 1832 that the industry began to assume anything like business proportions; but even then it was managed so badly that it remained very insignificant. A few wells were dug (as wells for water are dug), and the government even refused permission for an enterprising lessee to work with any kind of boring tools, the officer replying that such things had been tried, but that they had not succeeded, and consequently could not be tried again at Baku.

In 1850 the government gave a monopoly and limited the selling price of crude oil to 45 kopecks the pood, and received the sum of 200,000 rubles for the privilege. This monopoly was farmed out every four years to the best * * * bidder. In 1868 a commission was formed to take into consideration the industry. In 1872, in pursuance of its recommendations, the territory upon which there were surface indications was divided into plats of 25 acres each, and sold to the highest bidder by sealed proposals. By this time the field had attracted much attention, and the parcels were disposed of in some instances for enormous prices. In most cases, purchases were made by persons who had not the means to work their possessions, nor the experience had they possessed the capital. They, however, held on to their lands, and capital and experience were thus kept away, and the industry was worked in the most crude and unsatisfactory manner.

The product of the refineries was so bad, and the market so small, that there was not energy enough engaged to bring on a crisis in the industry. The government had placed an excise tax, which, under the circumstances, was unbearable, and for a time previous to 1878 the operators were upon the verge of ruin. No work was done except to fill contracts previously made. At Nishni-Novgorod there was in store more than one and a half millions of poods, almost 200,000 barrels, unsold, and the price had gone down from 3.50 to 1.30 rubles per pood. The government then removed the excise tax, and now there remains only a small tax collected by the town of Baku.

The real birth of the industry may be said to be the year 1872, when the lands passed into private hands. There have been since that time great but insufficient energy and activity displayed. The operators have no relations with each other. * * *

Many small owners, for want of means to work their property, have been obliged to sell, and some capitalists have entered simply as refiners, buying the crude oil for that purpose. Some of these refineries have grown to large proportions, and the principal ones are now making such improvements and changes as to make them first-class establishments, capable of enormous and thorough work.

He states further, as follows:

The territory now worked does not exceed six square miles. The principal field is at Balaxame, 9½ miles northeast of Baku, covering a territory of, say, 3½ by 1½ miles. Two miles south of Baku is a small field at Bēbēābat, on which there are some 25 wells. This is a very small territory, say three-fourths of a mile square. Ten miles southeast from Baku is an island. It is certain that oil exists there, but in what quantities is not known. Within a radius of 50 miles there are constant surface indications, and even some small wells.

In 1850 there were in all 136 wells. In 1862 there were 220, and in 1872 there were 415. These were wells dug as water wells are. In 1871 the first well was bored. In 1872 there was 1; in 1874, 50; in 1876, 101; in 1879, 301 bored wells in the district. The other wells had entirely ceased to be worked. During the year 1879, and so far in 1880 (August), there has been very much work done, but the exact figures are not attainable. The business is in a most confused condition now, in consequence of the changes that are being made. Many new wells have been commenced, and a very large number of those previously worked are being drilled deeper. If the figures given may be relied upon, that is, 301 wells up to 1879, it may now, perhaps, be said that on the 1st of July, 1880, about 500 wells had been commenced. Many of them are not completed, and some have been abandoned.

I have purposely omitted reference to the more or less highly colored accounts of the Baku "field of fire" and the "Persian fire-worshippers and their temples". The "field of fire" is described by Gruner (c) "as a broad expanse filled with fissures, from some of which inflammable gas escapes, and from others naphtha". Another speaks of it as a "wonderful sight; of green fields and waving corn, in the midst of which the removal of a foot or two of earth will reveal a jet of gas that will raise an enormous blaze if set on fire". (d)

a Consular Reports No. 1, October, 1880.

b Ruble, \$0.56; pood, 36 pounds.

c Ann. Génie Civil, iv, 845.

d Churchill, British consul to Resht, Persia.

SECTION 7.—HISTORICAL NOTICE OF THE PETROLEUM INDUSTRY OF GALICIA.

The petroleum fields of Wallachia, Moldavia, and Galicia lie upon the southern, eastern, and northern flanks of the mountain system that incloses Hungary from Russia and the plains of the Danube. This system embraces the Transylvanian Alps, the Siebenbürgen, and the Carpathians.

Oil springs have flowed in this region from time immemorial, and the oil has been collected and used by the inhabitants of the country and devoted to many of the rude and uncultivated wants of a people remote from the centers of civilization. In 1810 Josef Hecker and Johann Mitis obtained petroleum in Drohobycz district, and made a trial of the distilled and crude oil, which was obtained from dug wells and afterward treated in stills; but having worn out their still in 1818, their works were closed. In 1840, in the Stanislaw district, there were 75 dug wells and 6 establishments for the manufacture of wagon-grease. In 1853-'64 Schreiner boiled down petroleum and made a very superior article of grease, and his successor condensed the distillate and used it for illuminating purposes. The industry since that time, although conducted in a small way, had steadily increased until 1860-'65. (a)

Since 1860 a great deal has been written on the Galician oil-fields, and several spasmodic attempts have been made to find remunerative employment for capital in their development. This was especially the case in 1865, when the expansion of the production of Pennsylvania led to so many enterprises of a more or less experimental nature all over the world.

There are three localities particularly noted for their petroleum product. These are the neighborhood of Sandecer, in west Galicia; that of Böbrka, near Dukla, Sanoker, and Samborer, in middle Galicia; and Boryslav, in east Galicia. The latter locality is also celebrated for its production of ozokerite. The localities in Roumania that are now principally associated with petroleum are Sarrata, Bacan, Dimbovitsa, Prahova, Burzen, Moniezta, Plojezti, and Baikoi.

The oil was originally collected, as in other localities, from the water of the springs, with which it flowed from the crevices in rocks. It was afterward obtained from wells or shafts that were dug, and in Galicia and Roumania it is at present obtained in that primitive manner. Later the shafts were connected by galleries, forming what are called "complex mines" (complex Gruben) in Galicia.

The exploitations for oil at Mraznica consist of about 70 shafts in the upper part of the valley of Tiesmienka, the lowest row of shafts lying on both sides of the declivity of the Bachspiegels, with a second and a third row above them. They consist of the "old" complex mines, consisting of about 40 shafts, and the "new" complex mines, consisting of about 30 shafts. The older "complex mine" is going on 12 years old, having originated when the oil fever agitated Galicia. The first shafts were sunk by a Jewish company near an oil-spring to a depth of 100 meters (328 feet) with very satisfactory results, in consequence of which, and in order to control the production, they sunk many other shafts in the immediate neighborhood as soon as possible, and thus copied the Boryslav method of operation in the most destructive manner. The consequence was that they finally obtained from about 40 shafts the same quantity of oil that they could have had from 10 exploitations. A second oil-level, not yet reached, is supposed to exist, but the shafts have only penetrated 100 to 150 meters (328 to 492 feet). The largest yield from a single shaft is said to have amounted to 40 barrels of crude oil per week. Through ten years the most of the shafts have had an average flow of about 4 barrels per week; yet a single shaft is said to have yielded a net profit of 200,000 gulden (\$100,000), and has yielded petroleum for ten years up to 1878.

After a period of ten years the yield of oil decreased to such an extent that the enterprise became unprofitable. This caused the projector of the Jewish enterprise to attach the new "Gruben complex", consisting of 30 new-dug shafts, which likewise lay near each other in a compact mass, to the immediate upper half of the old shafts. In November, 1878, these shafts were sunk 20 to 50 meters (65 to 164 feet); yet they yielded no traces of petroleum particularly worthy of note. The extensive development of gas of the "old complex" was also entirely wanting. This failure is explained by assuming that the new shafts happened to lie within the circle already exhausted by the "old complex". Hence the petroleum industry in Mraznica must come to an end; yet, toward the close of 1878, 5 shafts still yielded about 14 barrels weekly. The long duration of the flow from these shafts is remarkable (ten years), while other springs in Galicia only flow an average of five years. (b)

Mraznica is in east Galicia. The facts set forth by Herr Walter explain why Consul-General Weaver reports December 30, 1880, that, of the yearly product of 100,000 barrels, produced in Galicia, two-thirds are at present obtained in west Galicia, in the vicinity of Grybow, where, during the census year, Mr. James Corrigan succeeded in establishing an American refinery. In a letter dated October 9, 1881, Mr. Corrigan states that a new well, yielding 75 barrels daily, had been struck at Slaboda, near the boundary of Bukowina (east Galicia), and that consequently great excitement prevailed.

a Ost. Zeit. f. Berg- und Hüttenwesen.

b Abstract of a portion of an article by Bruno Walter on "The chances of a petroleum production in Bukowina". J. K. K. G. R., xxx, 115 (1880).

SECTION 8.—HISTORICAL NOTICE OF THE PETROLEUM INDUSTRY OF CANADA.

The productive oil-fields of Canada lie in the county of Lamberton, in the western part of the province of Ontario, and principally in the township of Enniskillen. From the earliest settlement of the region "a dark oily substance had been observed floating on the surface of the water in the creeks and swamps. No matter how deep the wells were dug, the water was brackish and ill-smelling, and in some localities totally unfit for use; while a surface of black, oily slime frequently arose an inch thick, as cream rises on new milk. Here and there in the forest the ground consisted of a gummy, odoriferous tar-colored mud, of the consistence of putty. These places were known by the name of 'gum-beds', and in two or three instances were of considerable extent". (Henry's *Early and Later History of Petroleum*, p. 130.)

Operations were commenced there as early as 1857 by one Shaw, who dug an ordinary well, as for water, and after several days of digging struck a tremendous flow of oil, which ran in a stream into the creek. The usual phenomena attending such a discovery followed; land was bought and leased, more wells were dug, and oil flowed; they gathered what they could and wasted the remainder; fortunes were made and lost, and after a time, in 1864, the town of Oil Springs contained 3,000 inhabitants.

Flowing wells were struck here in 1862, and some of them proved the most prolific on record, rivaling those of the region around Baku. These great wells were exceptional, and the average yield has been comparatively small. The region over which borings have proved the existence of oil in paying quantities is about 50 miles north and south by 100 miles east and west, and within this range Petrolia, Bothwell, and Oil Springs have produced nearly all of the oil. The latter had the largest wells, though the former now produces more than nine-tenths of the amount at present obtained. Petrolia is about 16 miles southeast of the outlet of lake Huron, Oil Springs 7 miles south of Petrolia, and Bothwell about 35 miles from Oil Springs.

The petroleum of Canada contains sulphur and is difficult to refine, but its production has been fostered, and it supplies a large demand throughout the British provinces.

SECTION 9.—HISTORICAL NOTICE OF THE JAPANESE PETROLEUM INDUSTRY.

The knowledge of rock-oil in Japan is of great antiquity. In B. S. Lyman's reports (1877) appears the following:

It is said in the Japanese history called Kokushiriyaku (I am told) that rock-oil (or "burning water") was found in Echigo (in Nippon) in the reign of Tenjiteuno, which was 1,260 years ago, or about A. D. 615; and that was probably at Kusôdzu, where there are very old natural exposures as well as dug wells. The name of the place, Kusôdzu, is the name given in the country to rock-oil, and means stinking water; and the very fact that the word is by contraction so much changed from its original form, Kusai midra, shows of itself considerable antiquity.

In the Miyôhōji and Kusôdzu oil region there are (beside a much larger number of old, abandoned wells) about 178 productive wells, which altogether yield about 4½ barrels a day, making an average of about 1 gallon a day for each well. The best well is at Machikata, and yields about half a barrel a day. The best of the former wells was at Kitakata, and for fourteen days (in 1871) it yielded a daily average of 19 barrels, but after that only about 8 barrels a day. The deepest productive well of the region is 122 fathoms deep.

Reviewing all the Echigo oil-fields, we find that there are in all 522 productive wells, of which the deepest is 122 fathoms (732 feet) deep, the greatest yield is about 1.2 barrels a day, and the total yield about 26 barrels a day, giving an average of about 2 gallons a day for each well. Such a yield, if kept up through the whole year, summer and winter, would amount for all the wells together to 9,500 barrels a year, worth, at 12 gallons to the dollar, \$31,650.

At Shinano, on the other hand, the yield is far smaller. There are in that province, in spite of the numerous traces of oil and gas, only 22 productive wells, of which the deepest is 57 fathoms (342 feet) deep, and the best has a yield of 2½ barrels a day; and the total yield is a little over 5 barrels a day, or an average of 9½ gallons a day to each well; or, in a year, 1,900 barrels altogether, worth about \$6,250.

The whole yield of the two provinces, then, is about equal to that of two average Pennsylvania oil-wells. Yet two or three cases have occurred in Echigo of a yield of 15 to 19 barrels a day for a few days when the wells were new. At Miyôhōji they talk of having had a profit of \$70,000 to \$80,000 from a single well; and the general estimate of the yield of that field has been high.

Such was Mr. Lyman's (geologist of Japan) estimate of the product of the most fruitful oil-fields of Japan in September, 1876. Many other localities have been explored for petroleum with similar results; but the introduction of American refined oil at present prices has nearly destroyed the domestic trade, and has completely arrested the production.

In the very elaborate report made by Consul-General Van Buren in 1880 no mention is made of any domestic production of petroleum, although Consul Stahel, of Hiogo, shows that the imports of American refined petroleum into Japan have increased from about 1,000,000 gallons in 1872 to nearly 18,000,000 gallons in 1880. Hiogo has been one of the most important centers of the native petroleum trade, it having had a refinery.

SECTION 10.—HISTORICAL NOTICE OF THE PERUVIAN PETROLEUM INDUSTRY.

Previous to the outbreak of the war between Chili and Peru the prospect of a large development of petroleum in Peru was very flattering. The following statement of operations there has been widely copied, but I cannot vouch for its accuracy, as I have not been able to verify it:

Mr. Prentice, the Pennsylvania oil operator, in 1867, paid Peru a visit. A well was put down near Zorritos. At the depth of 146 feet a volcanic formation was reached by the drill, and oil was found. The well pumped 60 barrels a day. A second well was put down. Oil was reached at a depth of 220 feet. The yield rapidly declined from 12 barrels to 7 barrels a day. Mr. Prentice was satisfied that the

region would prove productive, but he held his own counsel. In 1876 he succeeded in securing the control of the entire estate for the purpose of producing oil. In that year the second well mentioned above was drilled to the depth of nearly 500 feet. The tools struck a vein of oil-bearing sandstone, and immediately sank 10 feet. This was the first finding of the sandstone. The strike was followed by a column of oil that filled the 6-inch casing and was thrown 70 feet in the air. In attempting to control the great flow by inserting tubing in the well the inexperienced employes let the tubing drop to the bottom. The side caved in soon afterward and stopped the flow. The well is still plugged. Mr. Prentice says its capacity will be 1,000 barrels a day. Another well of his near the above has been in use for three years. It has never yet been torpedoed or recapped. It yields 600 barrels a day. Mr. Prentice's experiments have proved that the deeper the wells are sunk the larger the yield is. At 600 feet he declares that a well in his Peruvian regions will pump 5,000 barrels a day. Back in the mountains some of his men have struck a vein of petroleum by merely digging a pit 28 feet deep. Several of these pits have been dug. Oil accumulates in them in paying quantities. Mr. Prentice has a refinery at Zorritos. Its capacity is 200 barrels; this he is now enlarging. There were shipped from the Pennsylvania oil regions in 1870, 1,085,615 gallons of oil to Peru, Chili, and Ecuador. Refined oil brings 25 cents a gallon in Peru and its neighboring states.

I have been informed that since the outbreak of the war nothing has been done in reference to this industry.

SECTION 11.—HISTORICAL NOTICE OF THE ITALIAN AND OTHER PETROLEUM INDUSTRIES.

I am indebted to Professor P. E. DeFerrari, C. E., of Genoa, for the following statement concerning the petroleum interests of Italy. His letter was dated Iglesias, Sardinia, December 22, 1881, and in it he says:

There are in Italy two large districts with petroleum-bearing strata: one in the north, on the southern borders of the Po valley; the other in the south of Italy. Unfortunately, in spite of extensive workings and a considerable amount of money employed in searching for mineral oil, no satisfactory result was obtained.

The chief localities where petroleum and its allied products are met with are—Po valley: Rivanazzano, province of Voghera; Riglio, province of Piacenza; Miano, in the Caro valley of Parma; Sapuolo, in the Secchia valley of Modena. South Italy: San Giovanni Incarico of Caserta; Coco, in the Pescara valley of Chieti.

In the first district the oil is of a very good quality, very pure, largely diffused in the rock, but occurs in strata chiefly of clay and argillaceous sand, which, because of their little permeability, do not permit the free exit of the oil when wells are dug in the ground. The geological range of the strata is the Miocene and Pliocene periods. Some geologists believe that below the above-mentioned strata there may be other strata which would yield large quantities of petroleum when pierced through with wells. It must be stated that these strata have not been found, even in those places where borings of 250 and even 400 meters have been opened (820 to 1,312 feet).

Six different societies have worked the petroleum springs of North Italy from the year 1866 to 1874, but without success. Several wells reached the depth of 200 meters (656 feet), but no large veins of petroleum were met with, and the works were abandoned. In the valley of Pescara, South Italy, there are also petroleum springs, with bituminous products. At Coco borings of great depth have shown the existence of some oil veins, but of little importance. At San Giovanni Incarico several veins of some hundred liters every twenty-four hours were found, but they have no industrial importance. Lately an Italian and French society, with large capital, and Canadian workmen and machinery, explored the ground at Rivanazzano and at Coco. They opened four wells 200 meters deep in the north; one 400 meters in the south (Coco); but the working was given up for deficiency of money. The whole product of petroleum in Italy does not exceed 300 tons a year, and it is chiefly collected in large and shallow wells by the country people, and used on the spot. No machinery worth mentioning, but small pumps, are used, and in most places the work is done simply by hand.

At Sapuolo and Salsomaggiore the gas which comes from crevices in the ground is collected and burned for industrial purposes. In the south of Italy bituminous clay is distilled and petroleum condensed in small quantity. The annual importation of petroleum into Italy is 50,000 tons, and its value is 14,500,000 francs.

This letter states the condition of the petroleum industry as related to modern methods of exploitation, and prices as governed by the enormous supply furnished at present by the United States; but petroleum has long been known in the valley of the Po, and many of its smaller towns have been lighted by it. The exceptionally fine quality of the petroleum of that region made it possible to use it without refining.

The earliest mention of petroleum from this region is by François Arioste, who cured men and animals afflicted with itch with petroleum which he had discovered in 1460 at Mont-Libio, in the duchy of Modena. (a) Agricola also mentions it in the middle of the sixteenth century. (b)

Many other localities will be enumerated in the succeeding chapter as furnishing petroleum, but those mentioned are the only ones that have furnished petroleum to the commerce of civilized nations.

The historical development of the petroleum industry may be summed up as follows: In many regions, and for immemorial periods, petroleum gathered from natural springs and dug wells has been used in medicine, and in a rude way as an illuminating agent. In China artesian wells have been bored for brine and for natural gas, and the latter was used to boil brine for centuries before the Christian era. In the United States artesian borings made for brine had furnished petroleum in enormous quantities thirty or forty years before any use was known for such a supply. The development of the coal-oil industry between 1850 and 1860 led to experiments upon petroleum as a substitute for the crude oil obtained from coal, and with the success of those experiments (1859) came a demand for petroleum that led to Drake's attempt to procure the oil directly by boring.

The success attending the oil industry in Pennsylvania during the first four years of its existence led to the organization of companies all over the world for the purpose of drilling test-wells wherever springs of petroleum were accessible. In some localities they were successful; in others only partially so; while in the majority of instances they were failures, or were found inferior to the primitive dug wells. The continuously increasing and enormous production of the United States, and the consequent depreciation in value of all the products manufactured from petroleum, has led to the almost complete control of that trade by American manufacturers, Galicia and the Caucasus at the present time being their only competitors, and they only to quite a limited extent.

a His book was published in 1690 by Jacob Oliger; *Comptes-Rendus*, ix, 217.

b *Comptes-Rendus*, ix, 217.

CHAPTER II.—THE GEOGRAPHICAL DISTRIBUTION OF PETROLEUM AND OTHER FORMS OF BITUMEN.

SECTION 1.—THE OCCURRENCE OF BITUMEN IN THE UNITED STATES.

The following chapter has been prepared for the purpose of showing the localities upon the earth's surface at which bitumen occurs, and great care has been taken to secure the most accurate information regarding the United States. For this purpose letters of inquiry have been addressed to the state geologists of all the states with which I am not personally acquainted, and to the geologist in charge of the geological survey of the United States. To these official sources of information has been added a large amount of personal inquiry and correspondence.

The map of the world (I) has been prepared to show the location of the areas producing bitumen. These areas are unavoidably exaggerated in size, and many localities of minor importance are omitted.

The map of the United States (II) shows the localities within the United States that have produced bitumen of any kind. Many of these areas are also unavoidably exaggerated in size.

The large map (III) shows the areas in Pennsylvania and New York that have proved commercially valuable. This map has been prepared from actual surveys, many of which were undertaken expressly for parties engaged in producing oil. The areas tinted yellow are believed to be substantially correct as regards both location and outlines. The streams were plotted with every attention to accuracy, and are believed to indicate the water-shed and lines of greatest elevation. The dates beneath the names of towns indicate the period at which the locality was yielding its maximum production. The red lines indicate the main pipe lines, and the broken blue lines indicate in a general way the outline of territory over which wells or natural springs have yielded petroleum or gas, but in most instances not a sufficient amount of petroleum to be profitable.

Map IV represents the areas at the White Oak district, West Virginia, drawn from actual surveys.

Map V shows the location of oil-wells in the valley of the Cumberland river in Kentucky and Tennessee, drawn from actual surveys.

Map VI represents in a general manner the localities in southern Ohio, West Virginia, and Kentucky that have produced bitumen.

Map VII represents in a general manner the localities in Louisiana and Texas that have produced bitumen.

Map VIII represents the localities in Michigan and Canada that have produced bitumen.

STATES AND TERRITORIES FROM WHICH NO BITUMEN HAS BEEN REPORTED.

Maine.	Maryland.	Mississippi.	Montana.
New Hampshire.	Virginia.	Arkansas.	Idaho.
Vermont.	North Carolina.	Iowa.	Washington.
Massachusetts.	South Carolina.	Wisconsin.	Oregon.
Rhode Island.	Georgia.	Minnesota.	Nevada.
Delaware.			

STATES AND TERRITORIES IN WHICH SOLID BITUMENS OCCUR.

CONNECTICUT.—In the valley of the Connecticut river solid bitumens have been observed filling thin seams and veins in eruptive rocks. (a)

NEW YORK.—In the eastern portion of the state, in the region of eruptive and metamorphic rocks, veins occur similar to those reported from Connecticut. (b) In some of the cavities of the New York limestones the crystals which line them are covered with a substance, black and shining, with the fracture and appearance of anthracite.

NEW JERSEY.—Veins are reported in the trap of New Jersey filled with a bituminous mineral. (c)

WEST VIRGINIA.—In Ritchie county, West Virginia, on McFarland's run, a small tributary of the south fork of Hughes' river, which enters the Little Kanawha, is found a vein of bituminous material, called asphaltum, which is without doubt closely related to petroleum and other forms of bitumen, but in precisely what manner has been a subject of much controversy. This vein cuts the nearly horizontal sandstone almost at right angles and stands vertical to the horizon. Very extensive mining operations were commenced upon the vein, but the mass was soon worked down to the lower level of the sandstones, and was found to pinch out in the shales beneath. It presented all of the appearances of an eruptive mass. The material was found to be exceedingly

a J. C. Percival on "Indurated Bitumen", *Geol. of Conn.*, A. J. S. (3), xvi, 130.

b L. C. Beck, A. J. S. (1), xlv, 335.

c J. C. Russell, A. J. S. (3), xvi, 112.

valuable for enriching gas, for which it was chiefly used; but a thickness of several hundred feet of shale, in which it was almost entirely wanting, prevented continuous working. Other smaller but otherwise similar veins occur in the neighborhood. (a)

TEXAS.—Near the mouth of the Brazos river and in other parts of Texas beds of asphaltum occur, evidently resulting from the decomposition of petroleum; but so far as I have been able to learn they have no commercial value.

NEW MEXICO AND ARIZONA.—In these territories beds of asphaltum are reported. They have no other than a local value.

UTAH.—In this territory, in the Sanpete valley, southeast of Salt lake, is said to be a deposit containing ozokerite similar to that found in Galicia. Also on the banks of the Green river veins are said to occur resembling the grahamite found in West Virginia. Although I have seen specimens which were said to have come from both of these localities, I have never met any detailed description of them. Neither deposit has yet any commercial value.

CALIFORNIA.—This state includes a large area which furnishes asphaltum, much the larger proportion being the product of the decomposition of petroleum, while the remainder occurs in veins that are evidently eruptive, (b) the former occurring in beds of greater or less extent on hillsides or gulch slopes below springs of more fluid bitumen. These deposits are scattered over the country between the bay of Monterey and San Diego, but are chiefly observed west and south of the coast ranges between Santa Barbara and the Soledad pass. In the aggregate there are thousands of tons of asphaltum scattered over this region of every possible degree of purity; but it is so difficult to handle, and so little is concentrated in one place, that little use has thus far been made of it.

The case is quite different, however, with the deposit at Hill's ranch, on the coast above Santa Barbara. Here eruptive masses that have been very fully described by Professor J. D. Whitney and myself (see note b) occur in such quantity that it has been obtained in cargoes for use in San Francisco. The asphaltum of this locality is solid and homogeneous in appearance, but it really contains 50 per cent. of sand, so fine and in such complete admixture as to make the material superior for pavement to any artificial mixture that can be produced. I have never been able to obtain even an approximate estimate of the quantity that this locality has furnished.

KENTUCKY.—Asphaltum is reported in Johnson county, on the tributaries of the Big Sandy river. I have never seen any of this asphalt, but I am inclined to think it is also more closely related to the gum beds of Canada, above mentioned.

TENNESSEE.—Asphaltum is reported in cavities and prisms in the Trenton limestone in middle Tennessee in small veins rarely an inch in thickness. The amount is insignificant.

OTHER LOCALITIES.—Asphaltum is also reported from other localities, in Missouri and Kentucky, but I have never seen any of the material, and from all that I have been able to learn regarding the deposits they resemble the so-called gum beds of Canada, which really consist of a mass of mud or soil saturated with petroleum, rather than of pure and solid asphaltum. Such mixtures of oil and mud are often met around oil-wells in any of the productive districts where the waste oil has soaked the ground about the derricks.

STATES AND TERRITORIES IN WHICH SEMI-SOLID BITUMEN (MALTHA) OCCURS.

This material issues from so-called tar-springs, and is found almost or quite exclusively within the southwestern portion of the country. I have seen but a single specimen from one of the interior counties of Texas. A letter of inquiry, addressed to the secretary of state of Texas, was referred to Mr. N. A. Taylor, who replied:

The tar-springs in Burnet county discharge a good deal of petroleum. The wagoners gather it to grease their wagon wheels. It is probable that borings there would get a good supply of oil. It appears on the surface of nearly all the springs at Sour lake. In days past it has evidently exuded from the ground at that place in great quantity, for there are some acres just below the lake almost completely covered with the consolidated stuff, or asphalt, the thickness of which I don't recollect, but no doubt it is very thick in some places. An attempt was made there to bore for the oil, but after penetrating the ground to some distance a great explosion occurred, and the fellow was afraid to try it again. I think some borings have also been made in Nacogdoches county. There is also a small lake in Marion county, where oil covers the water, and where there is also a good deal of asphalt. These counties are in northeast Texas. Burnet county is in the southern central portion of the state.

These tar-springs, which yield a semi-fluid maltha, are often called oil or petroleum springs by those who do not understand the difference in the value of these different although in some respects similar substances.

In New Mexico, not far from Albuquerque, tar-springs are reported; also in Arizona and southern Utah; but the exact localities I have been unable to learn or verify.

In southern California, throughout the same region in which asphalt is found, maltha occurs in great abundance, oozing from springs on the hillsides and in the beds of water-courses in cañons, and after exposure to the elements becoming hardened into asphaltum. In consistence it passes by insensible gradations from a material scarcely to be distinguished from heavy petroleum to solid asphalt. It varies in specific gravity from 0.9906 to 1.100, the heavier material, though heavier than water, still remaining plastic like mortar. Springs near the old stage-road between

a Lesley, J. P., P. A. P. S., ix, 183; A. J. S. (2), xli, 139; H. Wurtz: Report, 1865; S. F. Peckham, A. J. S. (2), xlviii, 362, Nov., 1869; A. G. J., xi, 164.

b J. D. Whitney: *Geology of California*. Geology, I, 132; S. F. Peckham, A. J. S. (2), xlviii, 368.

the Gaviota pass and the old mission of San Miguel (if my memory is correct) yield a quicksand cemented by maltha that oozes out and accumulates in great masses upon the side of the hill, becoming rigid as the maltha changes to asphalt. At Rincon point, about half way from Santa Barbara to San Buenaventura, a bed of sand overlying the shales, which there stand at a high angle, is saturated with maltha for about 20 feet in thickness over many hundreds of acres. The formation is exposed in the ocean bluff for at least a mile. Fig. 1 shows the manner in which the sand overlies the shale. (*a*)

Early in 1866, when trial-borings for petroleum were being conducted upon the San Francisco ranch, in the Santa Clara valley, Ventura county, maltha was found at a depth of 117 feet too dense to pump and without sufficient tenacity to admit of being drawn up with grappling hooks, yet sufficiently firm to clasp the tools and prevent further operations. On the plains northwest of Los Angeles an artesian boring that penetrated sandstones interstratified with shale to a depth of 460 feet yielded maltha.

In this region there are vast quantities of this material, which has not hitherto been found valuable, but which will no doubt at some future day be found useful in the arts. (*b*)

Maltha is also reported at the Shoshone springs, in Wyoming territory, and in cavities in the limestones of middle Tennessee. In the latter locality it occurs in small quantities, and has no commercial value.

STATES AND TERRITORIES IN WHICH LIQUID OR GASEOUS BITUMEN OCCURS.

NEW YORK.—In 1865 Jonathan Watson drilled a well in Ontario county, 5 miles east of Canandaigua lake, and found there a good oil-rock, plenty of gas, and a production of about 5 barrels of oil daily. A line drawn from this point west to lake Erie, and another south to the Pennsylvania line, would include all of the territory in the state of New York over which oil or gas has been obtained by boring (see map III), and along the shores of lake Erie, from the state line to Buffalo, at almost any point natural gas may be obtained from artesian borings. Fredonia, in Chautauqua county, a few miles south of Dunkirk, has been lighted by natural gas for more than forty years.

A great many wells have been bored along the lake shore and for some distance inland, and at a number of localities in Chautauqua and Erie counties they are reported to have produced small quantities of oil. In the southeastern portion of Chautauqua county, and that portion of Cattaraugus county north and west of Salamanca, the indications of a productive oil territory become more pronounced, but I have not been able to learn definitely that any wells in that region have yielded oil enough to pay their cost. The larger number of these wells were drilled many years ago, and detailed statements concerning their exact locality and the results afforded by them are now very difficult to obtain.

South and east of Salamanca the Bradford oil-field of Pennsylvania extends into New York, and has proved a very certain and valuable territory. The statements that are made in this report respecting the Bradford field apply equally to that portion lying in New York and in Pennsylvania. The field in New York lies south of the Allegheny river. (See map III.)

The next county east of Cattaraugus is Allegany, and at Cuba, in the southwestern part of that county, is the oil-spring described in 1833 by Professor Benjamin Silliman, sr. (*c*) Through the southern townships of this county the Richburg field has been recently opened with much promise. A few wells have been drilled in the southwestern part of Steuben county, but with what promise of commercial success has not yet been determined.

The wells in this region are from 1,600 to 2,000 feet in depth; the oil is of a dark amber color and of a specific gravity of 44° Baumé, very closely resembling that of the Bradford field.

PENNSYLVANIA.—A number of test wells have been drilled in the western part of Potter county, Pennsylvania, contiguous to Allegany county, New York, and some are reported to have yielded oil in small quantity, but most of them are understood to have been entirely unproductive.

The next county west is McKean county, and the greater portion of the Bradford field occupies that portion of the county embraced in about one-half the townships lying west and north of Smethport. As may be seen from the map (III) accompanying this report, the outline is irregular, with a small but detached portion lying to the southwest of the main body. This field has been developed since 1874, and while it has been very completely outlined by dry holes and wells of small production, there are many wells in different portions of the county outside the field that have yielded more or less oil. At Smethport a well yielded a "small quantity" of very dense amber-colored oil, while at Kane, in the southwestern part of the county, on the Pittsburgh and Erie railroad, is one of the most remarkable gas-wells on record. (*d*) The wells here are from 1,600 to 2,000 feet deep.

The next county west of McKean is Warren, and in it there are two well-defined productive fields of small extent. These are the Warren field, lying around the town of Warren, and the Clarendon and Stoneham field, lying to the south a short distance, yet entirely distinct from the former. These fields yield an amber oil of a specific gravity of 48° Baumé. The wells are from 800 to 1,100 feet deep.

a Report of Geological Survey of California: Geology, II. Appendix, p. 51, Fig. 2.

b S. F. Peckham, A. J. S. (2), xlviii, 370; Am. C., iv, 6.

c A. J. S., (1) xxiii, 97.

d C. A. Ashburner, J. F. I., cviii, 347; P. A. P. S., xviii, 9, 419; T. A. I. M. E., 1879, 1878, 316; A. J. S. (3), xvi, 393, xvii, 69, xix, 168; J. F. Carll, P. A. P. S., xvi, 346.

In the central, southern, and southwestern portions of Warren county, from Tidioute, on the Allegheny river, southwest into Venango county, the territory known as Triumph hill was opened in 1868. Some wells were bored in 1860 by the Economites in the river opposite Tidioute, and later upon the high land on the south side of the river. But this territory is small. On the north and west side of the river (which makes a bend just below Tidioute) a narrow belt of territory that has been very productive extends across the hills into Venango county. Northwest of this belt, in the southwestern corner of the county, a small territory around Enterprise proved very productive. Other noted localities in this section are Fagundus, southeast of Tidioute, and New London and Colorado, southwest of the same place.

The wells in the Warren and Stoneham fields are in a horizon which lies in depth between the Bradford and Venango county fields. Those on the island in the Allegheny river, first drilled by the Economites in 1860, were 120 feet deep; on the hills they are from 560 to 570 feet deep. The oil produced here is dark green by reflected light and of the color of brandy by transmitted light, resembling in this respect the oil of the so-called Oil creek. At Sheffield, in the southeastern part of this county, is another remarkable gas-well.

Erie and Crawford counties lie west of Warren county, and have both been pretty well drilled over. At Erie, on the lake shore, a number of gas-wells has for many years furnished gas to dwellings and manufacturing establishments, and a few wells sunk 600 to 700 feet in the shale have yielded a few barrels of heavy green oil, suitable for lubricating machinery. The most successful of these wells (the Demming) did not, so far as I could learn, pay the cost of drilling. The oil has a specific gravity of 26° Baumé. At Union City, in the southeastern part of Erie county, wells have also been drilled in shale which yielded a small quantity of very dense oil for a very long time. The first well was drilled in 1859, soon after Drake struck oil, to a depth of 52 feet, and has yielded a small quantity of oil ever since. Several other wells have been drilled here, but none of them, so far as I could learn, have ever proved profitable.

Mr. J. P. Stranahan, of Union, informed me that he and his brothers dug out an oil spring thirty-five years ago at Oxbow hill, a few miles northeast of Union, and that it had flowed oil ever since. The boys set the gas from the spring on fire and boiled eggs in the flame.

In 1879 a well was drilled 2½ miles west of Union, that struck oil in "paying quantities" at 18 feet. In going deeper to get more oil the well was spoiled, and was afterward abandoned; but I conclude that at better prices Erie county can be made to produce a considerable amount of heavy oil. At Girard and other points near the lake shore gas-wells are productive.

Crawford county, excepting in the southeast corner, along the valley of Oil creek, has about the same record as Erie county. Along the valley of French creek and its tributaries, above and below Meadville, many wells have been bored, some of which produced oil, but none in quantities that proved remunerative.

Titusville is near the line of Venango county, in the southern part of Crawford county, and north of Titusville is Church run, a locality that for a time proved very productive. This neighborhood has yielded oil from the date of Drake's well (1859) up to the present time. Drake's well was 69½ feet deep, and penetrated only to the first stratum of sandstone yielding oil; but after the wells were drilled deeper a second and a third sandstone were reached, and a much greater yield was obtained. The valley of Oil creek has been drilled all over, and nearly everywhere south from Church run it has proved productive. The portion, however, that lies in Crawford county is comparatively small.

South of Crawford county lie Mercer and Venango counties. Mercer county has been well drilled over with test wells, particularly the eastern portion, but without developing any territory of value. Venango county has proved one of the four most productive counties in the state, and if complete statistics from 1859 were to be had it would probably head the list. Oil creek enters near the middle of its northern boundary and runs a little east of south until it enters the Allegheny river near the center of the county, at Oil City. The Allegheny river enters the county near the middle of its eastern boundary, receives Oil creek at Oil City, and, flowing southwest, receives French creek at Franklin, from which point it flows southeast, and leaves the county at its southeast corner. The valley of Oil creek, the triangle between that creek and the Allegheny river, and the region below Franklin, on the same river, is crossed at intervals by long and narrow belts of territory, often from an eighth to a quarter of a mile wide and several miles in length, which have produced and are still producing oil in enormous quantities. These belts occupy long troughs or depressions, level on their upper surface, and curved upward from the center on the under surface from side to side. In a few instances the productive territories have been found to resemble pools in their outline and dimensions, but the major portion of this whole county is crossed by a great number of these belts which have yielded enormously productive wells in the center and less productive ones on parallel lines along the sides, until at a distance in some instances of 20 rods on either side the drill failed to reveal the presence of either sand or oil. The oil of this section has been quite uniform in character, excepting that produced in the neighborhood of Franklin, a small territory in the angle formed by French creek and the Allegheny river. In color it is for the most part green, although a considerable quantity has been obtained that is decidedly black. The specific gravity has varied from 42° to 48° Baumé.

The Franklin district has furnished a lubricating oil of very superior quality from shallow wells. These wells are almost all in Cherrytree township, Venango county; but a few are in Franklin on the high bluffs south of the city.

Forest county lies east of Venango county. Here several belts extend from one into the other, and several independent areas of small extent have been developed within its limits. West Hickory, Foxburg, and Balltown have been the principal centers, but the county, on the whole, has not proved to be very important for oil production.

The next county east is Elk, but as an oil-field is of less importance than Forest. A few wells have been drilled in its northwest corner, and others in the neighborhood of Wilcox have produced oil; but the production, as a whole, is unimportant. Near Wilcox is a noted gas-well.

Jefferson county, lying south of both Elk and Forest, has received some attention, but is without reputation. I have not learned that any of the wells reported to have been drilled there have yielded oil; they certainly have not in valuable quantity.

A glance at map III, accompanying this report, will show a large belt of oil territory having a general northeast and southwest direction lying in Clarion, Armstrong, and Butler counties. This belt begins in the southwest corner of Clarion county, passes through the northern part of Armstrong county, and extends nearly to the center of Butler county. The wells are from 900 to 1,300 feet in depth, becoming deeper as they approach the southwest extremity of the belt. This belt has been exceedingly productive throughout its entire area, and furnished the bulk of the oil production of Pennsylvania from 1869 to 1877. Small areas in each of the three counties have been developed outside the principal belt that have yielded in the aggregate a large amount of oil, but their importance has been so overshadowed by the main Butler and Clarion fields that they have been but little noticed. At Petrolia, in Armstrong county, gas-wells have proved very productive, and at Leechburg, on the Kiskiminitas, this gas has been used for manufacturing iron.

In the lower part of Armstrong county petroleum was obtained in 1839 in salt-wells, and was used for derrick lights.

West of Butler county, in Lawrence county, many wells have been drilled, with varying success. In the southeast corner of this county, on Slippery Rock creek, a belt has been developed that has been moderately prolific; but outside of this small area the county may be said to possess but little value for oil purposes.

South of Lawrence county, in Beaver county, a very valuable field has been opened up in the neighborhood of Smith's Ferry, on the north side of the Ohio river. This territory is between 3 and 4 miles square, and the oil is uniformly different from that produced in other portions of Pennsylvania and the adjoining states of Ohio and West Virginia. Being of a light amber color, resembling pale sherry wine, though not transparent, and having a specific gravity of 50° Baumé, it will burn in a lamp in hot weather without refining. This oil is much more valuable than the average of Pennsylvania oils.

Allegheny county lies east of Beaver, and near its center is the city of Pittsburgh. Along the Allegheny river above Pittsburgh, particularly near Tarentum, in the northeast part of the county, petroleum has been observed for 40 or 50 years, and it was here that Mr. Kier obtained the first oil that he refined at Pittsburgh. This county has never been regarded as valuable for oil purposes.

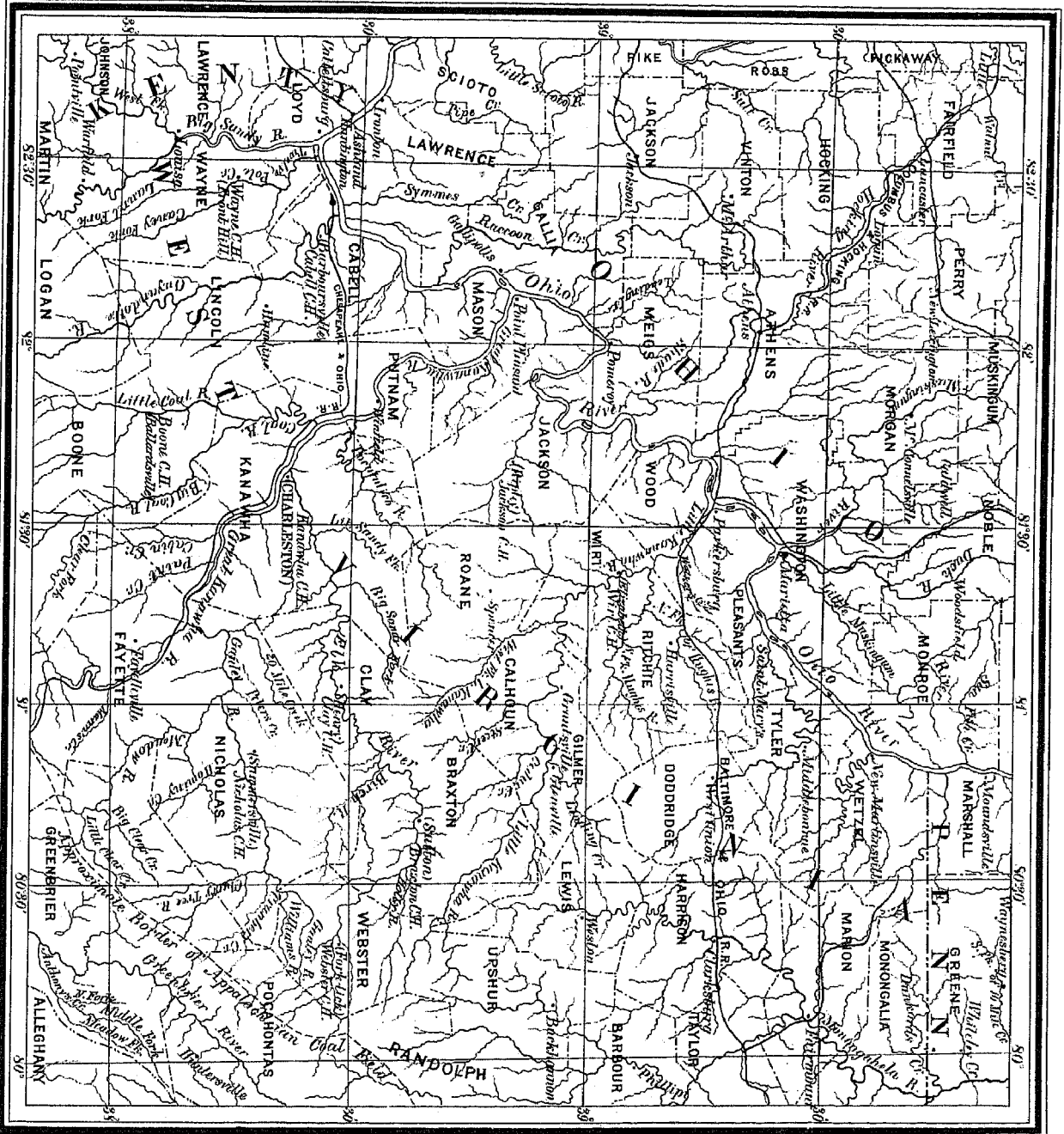
Oil suitable for lubrication has been obtained at Greensburg, in Westmoreland county, and many wells have been drilled in Washington county; but the production of oil has been practically nothing. In the southeast corner of Greene county, which is the southwest county of the state, an area on Dunkard's creek has produced a few thousand barrels yearly for several years, but the territory is small, and has been comparatively unimportant.

OHIO AND WEST VIRGINIA.—There are three localities in Ohio that have yielded petroleum from an early date. These are the neighborhood of Mecca, in Trumbull county, the neighborhood of Belden, in Lorain county, and Washington county.

Mecca is near the center of Trumbull county, which lies directly west of Mercer county, Pennsylvania. The oil produced here is from shallow wells, less than 100 feet in depth, is of a specific gravity of 26° Baumé, and of very superior quality as a lubricator. The territory is about 4 miles in length, north and south, by 2½ miles wide, and lies upon the west bank of Mosquito creek, with the village of Power's Corners near its center. Large sums of money have been expended in boring for oil in the valley of the Cuyahoga, where there are numerous springs; but none of the wells proved profitable, although a small quantity of oil was obtained in nearly all of them.

The Belden district, in the southeast part of Lorain county, is of about the same dimensions (4 by 2½ miles), but lies with its longer axis east and west. Several varieties of oil are produced here from wells of different depths. The more dense is black, and has a specific gravity of from 26° to 28° Baumé, while the lighter is green, and has a specific gravity of from 28° to 36° Baumé. It is supposed that this territory is larger than present developments would indicate, as wells have produced oil at Liverpool and at Medina, in Medina county, both of which are several miles east and southeast of Belden.

In the southeast portion of Columbiana county, a short distance west of the Smith's Ferry district, in Pennsylvania, many wells have yielded in the aggregate quite a large quantity of petroleum, although, as compared with other localities, the yield is unimportant.



The Washington county district extends into Noble, Morgan, and Athens counties, and for the most part lies in the valley of the Muskingum and its tributaries. Petroleum was obtained here in brine wells as early as 1814, and was noticed by Dr. Hildreth, of Marietta, in 1833, and again in 1836. (*a*)

The white oak anticlinal, or so-called "oil-break" of West Virginia, extends from Newell's run, a tributary of the Little Muskingum river, in Newport township, Washington county, Ohio, to Roane county, West Virginia, passing through Pleasants, Ritchie, Wood, and Wirt counties, of the latter state, reaching its highest point at Sand Hill, where the axis crosses Walker's creek, the rocks here being raised about 1,500 feet above their normal level. The crest is about one mile wide from side to side (east to west), in which the rocks are practically level, the stratification being as uniform as in the rocks outside of the anticlinal; but along its axis it is not level, forming there undulations, in which the whole depth of the formation shares. This brings the entire series in three elevations: the first one north at Horse Neck, in Pleasants county; the second at White Oak, in Wood county; and the third at Burning Springs, in Ritchie county. Oil is found under these three elevations, and consequently there are in West Virginia three contiguous districts that yield oil. (*b*) A few wells have yielded oil at the northern extremity of the uplift on Newell's run, in Ohio.

The territory of "Cow run" is situated in Lawrence township, Washington county, Ohio, about 3 miles west of the northern extremity of the white oak anticlinal. Here the rocks for about three-quarters of a mile square are raised 350 feet above their normal level, dipping off gradually on all sides.

The Macksburg territory is of limited extent, and is situated in Aurelius township, in the extreme northern part of Washington county.

At Olive, in Noble county, where the brine well of 1814 was located, petroleum has been obtained, and also in the Scioto valley, but not in paying quantities. (See Map VI.)

At Blue Rock, southeast of Zanesville, in Muskingum county, Buck run, in Morgan county, and Federal creek, in Athens county, a few wells have proved profitable. At Rutland, near Pomeroy, in Meigs county, near Gallipolis, in Gallia county, and on Tug fork of the Big Sandy river, in Wayne county, West Virginia, oil-springs have been observed. These localities lie in an almost direct line from Blue Rock to Tug fork, and are supposed to indicate a line along which wells will ultimately prove profitable.

There are several horizons in this region lying at different depths that yield oil of different specific gravities. The facts relating to this subject will be elucidated in Chapter III. (*c*)

Along the lake shore, at Ashtabula, Painesville, Cleveland, Rocky river, and other localities, gas-wells have yielded profitable supplies for heating and lighting dwellings. (*d*) At Liverpool, Columbiana county, Ohio, and across the river, at New Cumberland, Hancock county, West Virginia, gas-wells have yielded very large amounts for a long time, (*e*) the gas from which is used for lighting dwellings and factories and for the manufacture of lampblack. In Knox county some of the most remarkable gas-wells on record have been discovered in boring for oil. This gas is also used for the manufacture of lampblack. A further description of these wells will be given in the chapter devoted to natural gas. (*f*) At Burning Springs, Ritchie county, West Virginia, the escape of natural gas was noticed by the earliest settlers. (*g*)

At the salines, in the valley of the Great Kanawha, above and below Charleston, petroleum has been observed for at least fifty years, and for a time the natural gas which arose with the brine in nearly all of the wells was largely used for evaporating purposes; but while the aggregate production of this locality has no doubt been many thousands of barrels, it was for the most part obtained before petroleum became an article of large demand, and much of it was doubtless wasted. (See Map VI.)

KENTUCKY AND TENNESSEE.—The oil and burning springs that mark the line from Blue Rock, in Ohio, to the Tug fork of the Sandy river, in West Virginia, is continued in outcrops on Paint creek, Johnson county, Kentucky. This creek is a tributary of the west fork of the Big Sandy, and has been described by J. P. Lesley in his report published in 1865. (*h*) Springs are also met with near Saylorsville, in Magoffin county. In Lincoln, Rockcastle, Pulaski, Casey, Green, Adair, Russell, and Metcalfe counties oil-springs are found, and oil-wells have been drilled at different times. Some of these wells in Lincoln and Casey counties are old salt-wells, drilled fifty or sixty years ago; others are oil-wells drilled during the excitement of 1865 and 1878. The oil sand in Lincoln county lies at a depth of about 300 feet. A number of wells have been drilled in this county in the neighborhood of Stanford, all of which are reported to have reached oil, but the wells have not been piped or pumped, and none of the oil has been put upon the market. In Wayne county the oldest well in the country is still flowing oil. It was drilled for brine on the little south fork of the Cumberland river, in the southeast corner of the county, in 1818. The oil is heavy, black lubricating oil. Wells have been drilled near Monticello since 1865 that yield a heavy oil of a dark-green color, specific gravity 25° Baumé, that has a high reputation as a lubricator. In Clinton county oil was obtained in 1866; in Cumberland county the old American well was bored for brine in 1829 and flowed oil till 1860; and in 1865 a large number of wells were drilled along the Cumberland river and the creeks flowing into it, and they probably gave the most

a A. J. S. (1), xxiv, 63; xxix, 87.

b See sections, Plates III and IV.

c For many of the facts stated in this report respecting this region I am indebted to F. W. Minshall, esq., of Parkersburg, West Virginia.

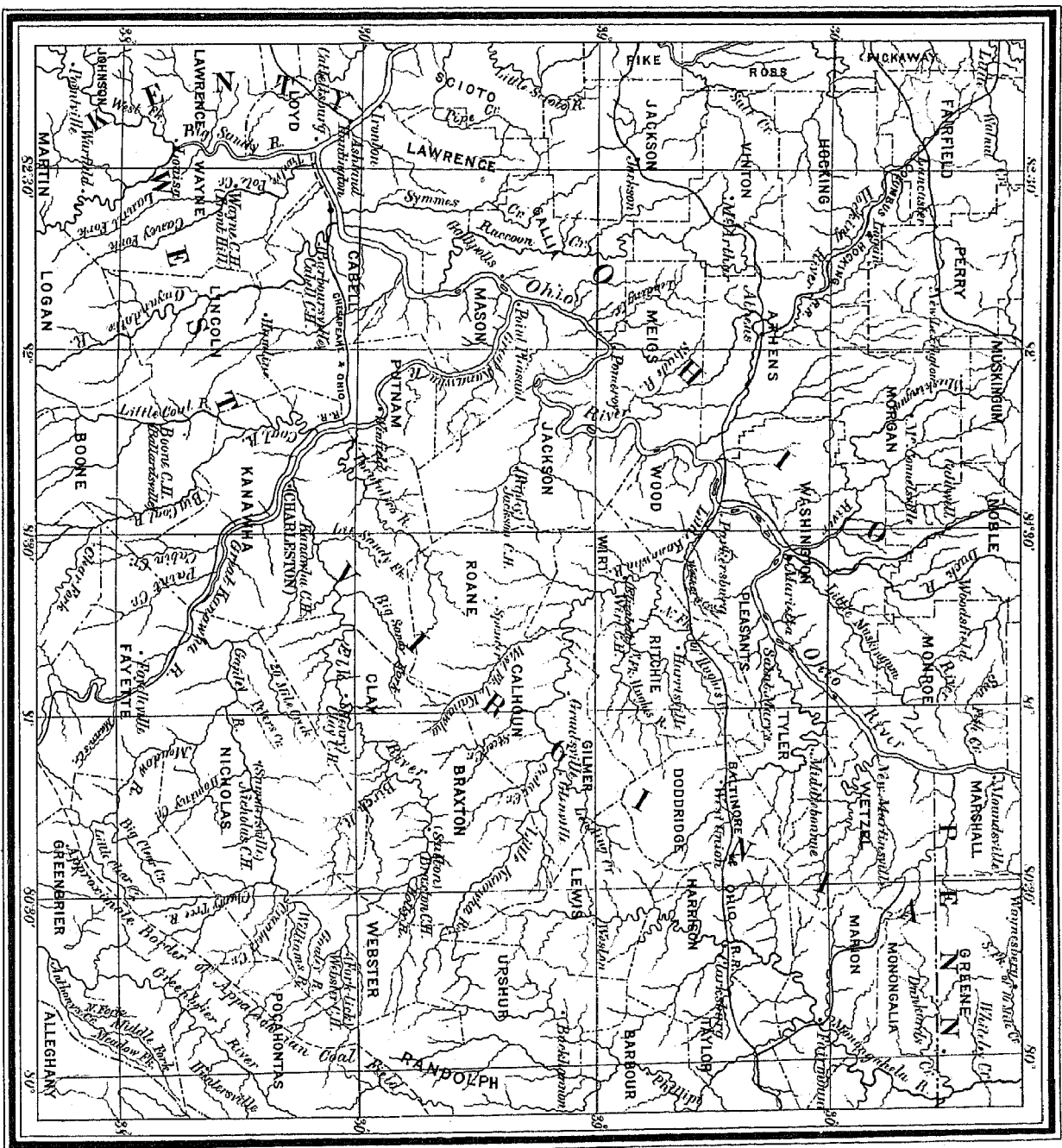
d J. S. Newberry, Geo. Ohio, i, 161.

e *Ibid.*, iii, 118.

f Geo. Ohio, 44.

g S. P. Hildreth, A. J. S. (1), xxix, 87, 121.

h P. A. P. S., x, 33.



certain and largest yield of oil that has ever been obtained for the same cost in any locality. At the same time, probably a larger proportion of the oil produced was wasted than has been the case anywhere else in the United States, as it is supposed that 50,000 barrels from the American well ran down the Cumberland river before any attempt was made to save it. The oil near Burkesville, Cumberland county, has a peculiar, offensive odor and a specific gravity of 37° Baumé. Amber oil of a lower specific gravity was obtained from other wells in small quantity, and a larger amount was yielded by wells on Oil fork of Bear creek (east of Burkesville), which was of a black color, with a specific gravity of 26° Baumé. The oil here appears to be in a sort of marble at 90, 190, and 380 feet from the surface.

On Boyd's creek, near Glasgow, Barren county, Kentucky, oil has been obtained for several years in commercial quantities, the wells being in the bed of the creek and on the adjoining hills. A few thousand barrels per year are obtained here. Wells have also reached oil on Beaver creek north of Glasgow. A well is also reported to have yielded "considerable quantities" of oil near Bowling Green, Warren county, and another near the Mammoth cave, in Edmonson county. (See Map V.)

Directly north of these counties, on the Ohio river, wells have reached oil at Brandensburg, in Meade county, at a depth of 900 feet; but those who drilled them afterward concluded that they were not deep enough. Three wells were also drilled near Cloverport, which yielded a small quantity of oil. Another well is reported in Bourbon county, and still another at Henderson, in Henderson county. This latter well is reported to have yielded a very valuable lubricating oil. Over at least one-third of the state scattering wells have yielded petroleum, some of which have been among the most remarkable in the country.

Springs of natural gas are common throughout the region just outlined; but I have not learned that the gas is anywhere used for any purpose, or that more than one well has ever been bored for gas, that at Bristow station, Warren county. Cumberland, Clinton, and Wayne counties, Kentucky, border Clay and Fentress counties, Tennessee, which, with Overton, Jackson, and Putnam counties, are drained by the east and west forks of Obey's river and other smaller tributaries, with Eagle and Spring creeks, all of which are tributaries of the Cumberland river. Many oil-springs are found in the valleys of these streams, and during 1867, 1868, and 1877 a number of wells were bored, almost uniformly producing oil, the larger part of which ran to waste for want of means of transportation. Trousdale, Macon, and Sumner counties, lying west of Jackson county and north of Nashville, also have oil-springs along some of their streams. To the west of Nashville about 40 miles another group of counties has oil-springs in the valleys of their streams, the principal field of operations being in Dickson county. Several wells drilled here from 1866-'69 to 1877 to a depth of between 400 and 600 feet yielded oil of a specific gravity of 44° Baumé.

In Hickman, Montgomery, and Maury counties there are springs, from one of which oil has been oozing since 1830, when it was opened by blasting for the foundation of a mill.

During the year 1863-'64 McMinnville, in Warren county, was the center of some activity in exploring for oil. A well sunk about forty years before for brine was sunk deeper for stronger brine. Oil flowed upon the creek, which took fire and destroyed the forests for 10 miles along its banks. Mr. M. C. Read visited this region in 1864, and found the agents of a Chicago company putting down five or six wells. These were located by witch-hazel men, at \$500 each, to be paid when they struck oil. Mr. Read asserted that there were several bottomless pits of petroleum beneath an intensely hard, cherty limestone, very difficult to drill. The company spent the first assessment before they got through that stratum, when, the price of oil falling, they pulled out their tools and left. Cannon county, adjoining Warren county on the west, has been examined during the last season and many springs of heavy oil have been discovered. Oil has also been reported in a well near Chattanooga. The counties that I have enumerated cover about one-sixth the area of the state. (See Map V.)

ALABAMA.—Jonathan Watson, esq., of Titusville, Pennsylvania, drilled wells in northern Alabama in 1865 and got oil in two of them.

FLORIDA.—It is reported to me that there are no petroleum springs in Florida. A. A. Robinson, commissioner of the board of immigration, Tallahassee, Florida, in a letter, says:

There is in the midst of an impenetrable cypress swamp near the coast, in Jefferson county, and about 35 miles southeast of Tallahassee, a mysterious column of black smoke, which has been rising for twenty years. At night it emits light, fitful and irregular, frequently lighting the sky so as to be seen miles away at sea. It is supposed to be a petroleum spring on fire. Much time, money, and enterprise has been expended to explore the swamp. No one has ever succeeded. It must be petroleum or a volcanic eruption. Some data may be found on the subject in the records of the United States coast survey.

MICHIGAN.—Oil and gas springs have been noticed on and near the shores of lake Huron and the entrance to the Saint Clair river. They are situated in several townships of Saint Clair county, not far from the city of Port Huron. A number of wells were bored near these springs in 1865, but none of the enterprises proved remunerative. (See Map VIII.)

ILLINOIS.—A well was bored at Chicago in 1865 that passed through strata that yielded petroleum both near the surface and at considerable depths. (a) The well was drilled for water. Recently a well has been reported as having been drilled in Montgomery county, a little north of east of Saint Louis, which yields a very heavy black oil, valuable as a lubricator.

INDIANA.—Wells drilled for water at Terre Haute in 1870-'71 showed petroleum, and afterward a well drilled purposely for oil yielded 25 barrels a day of a heavy green oil. In Crawford county, "during the oil excitement" from 1864 to 1868, ten wells were bored, and almost every one yielded "a show" of oil; but in no case could a yield of more than a pint a day be heard of, and in some cases only a few oily drops upon the surface of thousands of barrels of water were found.

The oil-supply rocks of this vicinity are so limited that there is hardly a possibility of striking a paying well, and some of the white-sulphur fountains now running from wells bored for oil are more valuable than any oil-well possible in the county. More than 20 oil-springs have been noted in this county: (a) E. T. Cox, in the *Geological Survey of Indiana for 1872*, page 139, says:

During the great oil excitement of 1865-'66 quite a number of wells were drilled in the northern part of this (Perry) county, on the waters of Anderson and Oil creeks. These wells were generally carried to a depth of 700 feet, and in one or two of them was found a little oil and gas. Though it is extremely doubtful if oil in paying quantities can be found in the county, still I do not believe that these wells were carried to a sufficient depth to reach the corniferous and Niagara limestones, from whence the oil is obtained in the Terre Haute well.

Perry county joins Crawford county on its eastern border, and also contains oil-springs. In Lawrence county indications of petroleum have also been noted. Perry and Crawford counties, Indiana, are north of and opposite Breckinridge and Meade counties, Kentucky.

MISSOURI.—Some wells were drilled in this state about 1865-'68. A letter from Professor G. C. Swallow says:

A well was sunk on Mr. Boyd's land in Sec. 21, T. 33, R. 33, Barton county, 130 feet, without obtaining any considerable quantity of oil. Another well was sunk in Sec. 35, T. 34, R. 32, to the depth of 525 feet, principally in sandstone and shale; very little oil was found. In Barton and Bates counties oil often rises on the water of many springs in small quantities. In La Fayette county a well was sunk to a depth of some 600 feet through sandstone, shale, coal, and limestone. Very little oil was found, and none was saved. It appeared on the surface in a sandstone, and this led to the work upon the well. Another well was sunk in Ray county, from which small quantities were obtained. In Ray county oil often rises with the spring water and consolidates into asphaltum; in fact, there is no prospect of ever finding any oil in paying quantities in Missouri, though it comes to the surface in springs in hundreds of places in the region of the coal measures.

Ray and La Fayette counties are on either side of the Missouri river near the western boundary of the state; Bates and Barton counties are farther south, and are drained by the tributaries of the Osage river. Oil-springs are also reported in Cass county, north of Bates.

KANSAS.—Miami county, Kansas, is west of Bates county, Missouri, and is also drained by the tributaries of the Osage river. Oil and tar springs abound in this county, and oil was obtained in the salt-wells at Osawatimie, Paola, and other places. In 1860 a well was bored 275 feet deep on Sec. 15, T. 17, R. 23, and "they got oil all the way down". It is supposed it would yield one barrel a day. Another well was bored in 1865 on Sec. 11, T. 17, R. 24. Oil-springs are also reported in Linn county. The oils are all black and heavy, and are fit only for lubrication. (b)

LOUISIANA.—In the low lands bordering on the Calcasieu and Sabine rivers there are numerous springs of petroleum. (c) (See Map VII.)

NEBRASKA.—In a communication to S. F. Peckham from Professor Samuel Aughey appears the following:

No petroleum springs, as such, are known in Nebraska. No wells have been drilled purposely for oil. In boring for coal at Ponca, Dixon county, a small amount of oil rose to the surface from a depth of 370 feet. I obtained only about a spoonful by saturating woolen cloths. Don't amount to anything. The same traces of oil have been obtained this season in boring for coal at Decatur, Burt county. I have observed genuine petroleum floating in the north Platte river above the mouth of Willow creek, in extreme western Nebraska. Thus far I have failed in my efforts to trace it to its source.

Dixon and Burt counties are on the west bank of the Missouri river, in northeast Nebraska.

MONTANA, WYOMING, DAKOTA, COLORADO, AND NEW MEXICO.—A letter addressed to the director of the United States geological survey, July 6, 1881, in which inquiries were made regarding the occurrence of petroleum in the territories, was referred to the different geologists in charge of those regions, and in reference to those named above S. F. Emmons replied as follows:

Certain horizons of the cretaceous sandstones in the Rocky mountain region are more or less impregnated with hydrocarbons, and when sufficiently and systematically examined will be very likely, in favored localities, to yield merchantable petroleum in considerable amount, if the conditions are such as to make it pay. As yet, however, but little has been done, and the returns of my experts, who were instructed to report on any petroleum wells that they could hear of, contain no schedules on this industry. The only information I can give you, therefore, is of the most general description. * * * Actual springs of petroleum I have not seen, though I have occasionally heard of a little oil on the surface of water. Considerable thickness of sandstones was observed by me on the southern slopes of the Uinta mountains, notably in Ashley creek basin, which were black with carbonaceous matter. The weathered surfaces, however, had lost all of their volatile ingredients, and doubtless suffered thereby some chemical change; so that it was more of an asphaltic material that was left. In the neighborhood of Bear River City, on the Union Pacific railroad, near the boundary of Utah and Wyoming, and also about 15 miles east of there, in the hills, wells were sunk, from which a few barrels of petroleum were obtained, but I fancy it never proved a pecuniary success. The supply was small, and the product of too little value to pay for working. This was nine or ten years since.

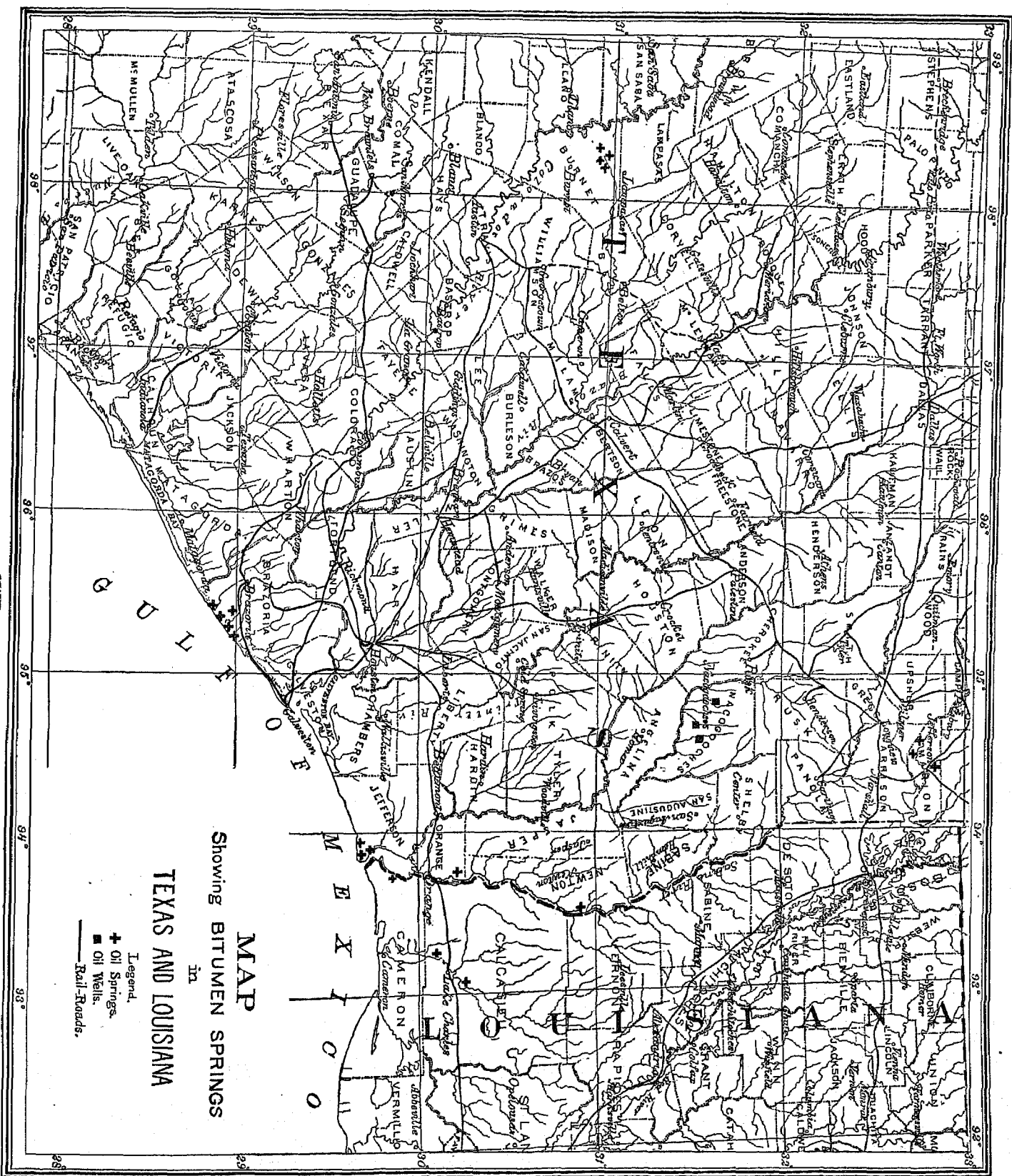
I heard of a man who claimed to have a petroleum well somewhere between the south end of the Wind river and the Big Horn mountains from which he was obtaining an excellent lubricating oil, and which he sold at a high price. Some excitement was spoken of in the papers a year or two since about petroleum on the west slopes of the Black hills of Dakota; and there has been talk of some out on the hills to the

a *Geological Survey of Indiana*, 1878, p. 520.

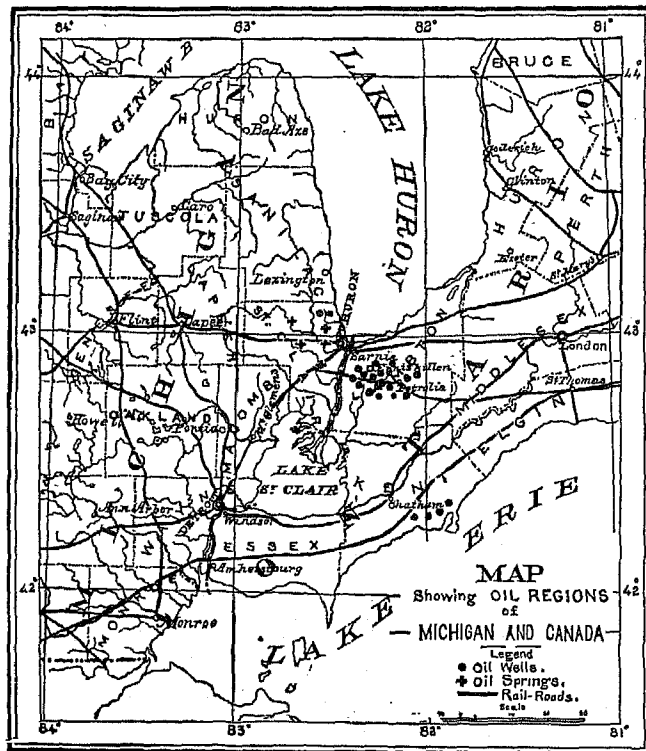
b *Report of Geological Survey of Miami county, Kansas*, by G. C. Swallow. 1865. Kansas City, Missouri.

c Professor William M. Carpenter, A. J. S. (1), xxxv, 345.

MAP VII.



MAP VIII.



northeast of the same, though I hear nothing of them lately. All these points would strike the same cretaceous rocks, but are too far away from lines of communication to encourage capital to develop at present. Within the past year some coal company "struck oil" in a well on their property a few miles south of Cañon City.

In brief, then, as far as I know, there is no actual production of petroleum in my district; it exists, however, in the cretaceous rocks which extend over the greater part of it along the eastern slope of the Rocky mountains from British Columbia to Mexico and in many of the interior valleys. Blake's map, published in the Ninth Census, will give you a rough general idea of the extent of this formation. Whether the petroleum thus existing can be made to pay, whether it is concentrated in sufficient quantity, or is of good enough quality, can only be satisfactorily proved by practical experiment. I think myself it will probably do so in time, locally, at any rate; but, owing to low price, it may be some years yet before labor and other conditions favor the development.

An artesian well at Yankton, Yankton county, Dakota, 300 feet deep, is reported to have struck blue shale which is saturated with petroleum.

Returns have been made to the Census Office from two parties in Wyoming. The first is located 75 miles north of Point of Rocks station, on the Union Pacific railroad, and south of the Shoshone Indian reservation, in Sweetwater county. This property is reported to consist of ten or twelve springs and a well 60 feet deep. The oil is very heavy—19° Baumé. The second locality is southwest of the Black hills, in Laramie county, near the Dakota line, 25 miles northwest of the junction of the east and west forks of Beaver creek. This property consists of springs of water, from the surface of which the oil is collected and strained, and supplies a local market.

CALIFORNIA.—Bitumen is distributed very generally throughout the coast ranges from San Francisco bay south to Los Angeles county, and petroleum is reported to have been obtained in a well on Tunitas creek, San Mateo county. The extensive operations of the Pacific Coast Oil Company are reported to be located in Lexington township, Santa Clara county, but I have been unable to learn any particulars in reference to the production of their wells. Tar-springs are found through Monterey, San Luis Obispo, Santa Barbara, Ventura, and Los Angeles counties. In the Santa Clara valley, in Ventura county, and in the hills on both sides of it, much money has been expended during the last seventeen years, and some oil has been obtained, the principal localities having been in the cañons of the Sulphur mountain that border the Ojai ranch on the south, at the mouth of the Sespé cañon, further east, and both east and west of Petrolia, near the upper end of the valley; but it is impossible at this distance to express an opinion respecting the real value of the operations or the product obtained. The opinion that I expressed in 1866, in a report that I at that time submitted to Professor J. D. Whitney, then state geologist, I believe has been justified in every particular, so far as the Santa Clara valley is concerned.

In the *Report of the Geological Survey of California* (Geology, II), appendix, page 73, it appears as follows:

The expectation of extraordinary results, that will admit of comparison with those that have been produced in Pennsylvania, must be set aside. The expectation of a fair return and a permanently profitable investment may be reasonably entertained; and the application of capital on this basis to this interest will make it of great importance to the state, and especially to that particular section in which the bituminous outcrops occur.

SECTION 2.—GEOGRAPHICAL DISTRIBUTION OF BITUMEN IN FOREIGN COUNTRIES.

The notices of bitumen in foreign countries do not admit of very exact classification, as the name petroleum has been from early times applied indiscriminately to nearly every form of bitumen by writers but little acquainted with the subject.

BRITISH AMERICA.—Bituminous minerals, often solid when they appear upon the surface, but more frequently semi-fluid or fluid, occur at many localities in British America. Petroleum has been almost without exception obtained by boring.

Bituminous schists, called petroleum schists, have been observed on the banks of the Mackenzie river; (a) also near fort McLeod, 260 miles north of fort Benton, Montana, and at another point 36 miles southwest of the same point, near the 114th meridian, on the Taylor farm. (b) In the valley of the Elk river that empties into Athabaska lake "there is a peaty bog, whose crevices are filled with petroleum, a mineral that exists in great abundance in this district. We never observed it flowing from the limestone, but always above it, and generally agglutinating the beds of sand into a kind of pitchy sandstone. Sometimes fragments of this stone contain so much petroleum as to float down the stream". (c) The occurrence of petroleum or bitumen on the Athabaska was recorded by Sir Alexander Mackenzie in 1789, and again by Sir John Richardson in 1851. The first-named author states, on page 87 of his narrative, alluding to the forks of the Athabaska or Elk river, that "at about 24 miles from the forks are some bituminous fountains, into which a pole 20 feet long can be inserted without the least resistance. The bitumen is in a fluid state; heated, it emits a smell like that of sea coal". Sir John Richardson says: "The whole country for many miles is so full of bitumen that it flows readily into a pit dug a few feet below the surface."

On the Abittibi river, south of Hudson's bay, petroleum is reported, occurring in strata resembling those just mentioned. (d)

a E. Heibert, B. G. S. F. (3), iii, 87.

b J. C. Nelson, of the Dominion surveyor-general's office.

c Account of the route to be pursued by the Arctic Land Expedition in search of Captain Ross, by Captain Back, R. N., *Jour. Roy. Geog. Soc.*, iii, 65, 1833.

d *Descriptive Catalogue of the Minerals of Canada at the Philadelphia Exhibition*, page 63.

A number of localities are mentioned where petroleum occurs in Newfoundland, among them West bay, Port-au-Port bay, Piccadilly, and a point between Bonne bay and Saint John's island, to the north of Cow harbor. (a) At lake Ainslee, on Cape Breton island, petroleum springs occur, and a number of borings have been made without success. At Kempt, Nova Scotia, limestone occurs, in which petroleum is found of a honey-yellow color in small cavities which are lined with crystals of calcite. (b) Petroleum is also reported at Hillsborough, New Brunswick. Here also occurred the deposit of albertite which for a number of years, like the grahamite of West Virginia, was very famous. It is of eruptive origin, filling a vertical fissure in shale. It was at first extensively used for the production of coal-oils before the introduction of petroleum, and afterward, like grahamite, for enriching gas coals. The deposit is practically worked out and the mine is abandoned.

Petroleum springs were first mentioned at Gaspé, near the entrance to the gulf of Saint Lawrence on the south, in 1844, by Sir W. E. Logan. They have since been noticed in successive reports of the Canadian geological survey, and were in 1865 made the subject of a special report by Dr. T. S. Hunt, in which he mentions a number of localities in the neighborhood of Tar Point, Douglastown, and other places in the neighborhood of Gaspé bay, along a line of 20 miles, where the rocks are impregnated with solid, semi-solid, and liquid bitumens, which ooze from them at many points. Several wells were drilled here, but in none of these localities do the springs yield any large quantities of oil, nor have the borings which have been made in two places been as yet successful. (c)

In reply to inquiries made in June, 1881, Dr. A. R. O. Selwyn, director of the geological survey of Canada, says :

As regards Gaspé and Cape Breton, the question is easy. Petroleum has been found, but never in sufficient quantity to be commercially available.

Wells were drilled near Wequamikong, Great Manitoulin island, in lake Huron, in 1865, and oil was obtained, but not in remunerative quantities.

The productive oil-fields of Canada lie in the county of Lamberton, in the western part of the province of Ontario, and principally in the township of Enniskillen, around the village of Petrolia. In the *Descriptive Catalogue of the Minerals of Canada at the Philadelphia Exhibition*, page 61, appears the following :

The whole oil-producing region around Petrolia has an area of about 11 square miles, with its longest diameter running about north-northwest. The bluish clay of the surface has a pretty uniform depth of about 100 feet, and beneath it borings penetrate an average thickness of 380 feet of interstratified bluish-gray dolomites, shales, and marls (the last being locally known as "soapstone") to the most productive stratum, or 480 feet in all. At first many of the wells both at Oil Springs and Petrolia flowed spontaneously, but now they all require to be pumped. The oil is accompanied by sulphurous saline water, and has an offensive odor. The difficulty in getting rid of this odor at first stood much in the way of the successful competition of the Canadian petroleum with mineral oils from other countries; but since the refineries have been able to thoroughly accomplish this, it has been acknowledged to be a very superior burning oil.

Theo. D. Rand, J. F. I., LXXX, 59, says:

In 1861 numerous wells were sunk, many through the surface clay only, others one or two hundred feet in the rock, and oil was everywhere obtained in fair quantity. During the winter of 1861-'62 and the following spring the great flowing wells which have made this region so famous were struck one after another. The yield from these wells was enormous, ranging by estimate from 1,000 to 7,000 barrels a day.

MEXICO.—A vein resembling albertite is reported in the state of Guerrero, 170 miles from the city of Mexico, and petroleum of a beautiful light-straw color and a density of $32\frac{1}{2}^{\circ}$ Baumé is reported from near the city of Mexico. (d) It is also reported from laguna Tampamachoco, on the north side of the Tuxpan river, on the gulf of Mexico, 20 miles from Tuxpan. Tar-springs are reported to rise in the gulf of Tampico, and their products float ashore.

About 20 miles from the bar of the river Coatzacoalcas, that rises on the isthmus of Tehuantepec and empties into the bay of Campeche, and half a mile inland, the "laguna del Alquitrán", or lake of Tar, is thus described:

It is surrounded by tall grass, and measures upward of an acre in extent. The exterior crust is a compact layer, sufficiently solid to enable one to walk around its border; but the center is soft, and under the rays of a vertical sun the surface shines like polished jet. In many places there are diminutive ponds of water tinged with iridescent colors, while in others the fluid bitumen bubbles up as if in a constant state of ebullition. Sometimes these bubbles are aggregated so as to form small cones three and four feet high, which evolve vapors, burst, and overflow. As a proof that the petroleum springs of the isthmus are subterraneously connected, I may mention that whenever an ebullition or a spontaneous conflagration occurs in the lake of Tar it is at the same time repeated in all the others, although widely separated. At rare intervals, about once a year, the lake of Tar is spontaneously ignited, and the whole surface is covered with a sheet of flame, which is accompanied by volumes of dense smoke, impregnating the air with powerful bituminous odors. On the day of our visit one of these spontaneous conflagrations took place, and continued to burn until after sunset. The heat arising from the flames was very great, and the sky was darkened by clouds of black smoke that arose above the lake, recalling the descriptions given of the Caspian "field of fire". I learned that within a league and a half, in a southeasterly direction from the right bank of the Coachapa, a tributary of the Coatzacoalcas, there are six smaller lakes, clustered together within a space of 300 acres. (e)

Other localities less remarkable were visited in the vicinity, and immense quantities of asphaltum are said to occur along the shores of the Gulf of Mexico above and below the mouth of the river.

a *Geological Survey of Canada*, 1877-'78, c. 24; John Milne, F. R. S., J. G. S. L., xxx, 738.

b D. Honeyman, A. J. S. (3), i, 386.

c *Geol. Canada*, 1862, pp. 788, 789.

d Am. C., ii, 290.

e *Report on Petroleum in Mexico*, by John McLeod Murphy, 1865.

THE WEST INDIES.—In 1837 Professor R. C. Taylor described a vein of solid bitumen that occurs at Casualidad, three leagues east of Havana, Cuba. He describes the mass as a wedge-shaped vein “filled with carbonaceous matter, as if injected from below”. He calls the substance coal, but shows that it is very unlike ordinary coal, both in its specific characteristics and in the mode of its occurrence, and says:

In whatever way we may account for the origin of this remarkable coal deposit, we must be led to view it in some measure in connection with the petroleum which is found in the rocks of this region. The petroleum springs which rise from fissures in the Serpentine at Guanabacoa have been known for two centuries. Nearly contemporaneously with the discovery of the coal of Casualidad, it has been observed about midway between the cities of Matanzas and Havana, not far from the sea-coast. (a)

The strike of the Casualidad vein is nearly north and south, conforming to the local range of stratification, although the general range is east and west, following the general direction of the island. At the outcrop the vein is scarcely a foot thick, but at the depth of 30 feet it is enlarged to 9 feet, descending nearly vertically. Other positions in the neighborhood of the principal mine of this substance show its prevalence in the country. We have examined and reported upon some excavations two leagues from Havana, on the road to Tapozte. (b)

Even in the bay of Havana the shore abounds with asphalt and bituminous shales in sufficient quantity for the paying of vessels, as a substitute for tar. It is stated that in buccaneering times signals used to be made by firing masses of this chapapote, whose dense columns of smoke could be recognized at great distances. It is matter of history that Havana was originally named by the early settlers “Carine”; “for there we careened our ships, and we pitched them with the natural tar, which we found lying in abundance upon the shores of this beautiful bay.” Petroleum leaks out in numberless places in this delightful island from amid the fissures of the Serpentine, and perhaps has deeply-seated sources. We are acquainted with abundant springs of petroleum between Holquin and Mayari in the eastern part of the island, and we possess notices of others in the direction of Santiago de Cuba. In fact, the entire chain of the West India and Windward islands present similar phenomena of petroleum springs. (c)

The reputation of Cuba asphaltum, or chapapote, is too well known to require comment, as it is exported from the island both to the United States and to Europe. Petroleum has never been found there in such quantities as to be commercially important.

Petroleum was reported as occurring in San Domingo by William M. Gabb, esq., who made a geological reconnaissance of the island in 1872. It occurs about three miles from Azua, in the southwestern part of the Dominican republic, on a stream called El Agua Hediondo, or Stinking Water. An unsuccessful attempt was made to bore here in 1865-'66. The product of the springs is a thick maltha, of a density of $22\frac{1}{2}^{\circ}$ Baumé = 0.945, which does not yield paraffine. (d)

The petroleum of Barbadoes was described in 1750 by Griffith Hughes, in a work entitled *Natural History of the Island of Barbadoes*. He says:

The most remarkable fossils of bituminous kind is green tar. It is obtained by digging holes or a trench, and it rises on the water. It issues from hills, and is gathered in the months of January, February, and March, and serves to burn in lamps. Munjack is dug out of veins. It is stated that one of these veins was fired by a negro, who built a fire on a hillside to roast potatoes, and it continued to burn for five years.

The heavy, dark-green or black petroleum was an article of commerce, under the title “Barbadoes tar”, for many years prior to the introduction of petroleum for illuminating purposes.

The Pitch lake of Trinidad is the most extensive known deposit of asphaltum. It was described by Dr. Nugent in 1811, (e) by G. P. Wall, esq., in 1860, (f) and by Professor T. Rupert Jones in 1866. (g) The lake is about three miles in circumference, and is described as a mass of asphaltum, sloping to the northern sea-coast. Although firm enough to bear a team of horses, it is still somewhat plastic, and appears to be in motion toward several points that act as vortices, as the trunks of trees disappear and after a time emerge at some distance from the point at which they sunk. Small lakes and streams of water abounding in fish are described as distributed over the surface, with numerous islands covered with tropical verdure. The asphaltum is exported from the island to the United States and Europe, where it is used for the preparation of roofing materials and in the preparation of mastic pavements. It does not yield paraffine on distillation, and has not, therefore, been proved valuable in the arts for the purposes to which albertite, grahamite, and other similar substances are applied. In 1857-'58 an attempt was made to manufacture illuminating and other oils from the pitch, and Mr. William Atwood spent more than a year there superintending operations on the island; but that and all other attempts to use the material for such purposes have failed. It is, however, applied to other uses in the arts in enormous quantities, and the supply appears to be practically inexhaustible.

“South of cape de la Brea is a submarine volcano, which occasionally boils up and discharges a quantity of petroleum. Another occurs on the east side of the island, which throws up on the shore masses of bitumen.” (h)

SOUTH AMERICA.—Humboldt mentions in his personal narrative the occurrence of petroleum springs in the bay of Cumana, where the oily fluid rises and spreads upon the surface of the sea. (i) Wall mentions the occurrence of asphaltum in the province of Maturin, on the mainland opposite Trinidad, and observes that other districts of the Llanos are generally affirmed to furnish it, although he did not examine them. (j) On the northern shores of the United States of Colombia and along the Magdalena river asphaltum is reported in immense quantities.

a *Philosophical Magazine*, x, 161-167.

b *Taylor's Statistics of Coal*, p. 578.

c *Ibid.*, page 579.

d E. Waller, *Am. C.*, ii, 220.

e T. G. S. (1), i, 63.

f Q. J. G. S., xvi, 467.

g *Ibid.*, xxii, 592.

h *Taylor's Statistics of Coal*, p. 584.

i *Travels*, Bohn's ed., i, 198; ii, 113.

j Q. J. G. S., xvi, 467.

Under date of August 10, 1880, Commercial Agent Plumacher, of Maracaibo, gives a very elaborate description of the petroleum deposits of Venezuela, from which I infer that the slopes of the Cordilleras that inclose the lake of Maracaibo abound in asphaltum, maltha, and petroleum. It is difficult, however, for one locally unacquainted to eliminate reliable details from the report.

Petroleum is reported in Ecuador at Santa Elena, along the sea-shore, and Henry, in his *Early and Later History of Petroleum*, page 144, says:

Pits from 10 to 12 feet deep are dug into the sand till clay is reached, and, when the oil which oozes from all sides has filled them, it is dipped out. Near the wells are primitive furnaces, built with sun-dried clay, on which are open iron boilers. The bituminous matter is thrown into these vases and cooked until all the volatile products disappear and leave a thick pitch.

A well-known region in northern Peru near Payta, on the Pacific coast, is undoubtedly very rich in petroleum. The existence of this material was known in Peru before the conquest, as a mummy of date prior to that event in the Peabody Museum of Archaeology of Harvard University has been prepared with it. The pitch was also used for coating earthenware on the inside, particularly liquor jars.

Several wells have been bored here, one of which produced several hundred barrels daily, and it is claimed by those who are conducting the operations that flowing wells may be obtained with great certainty over an area many miles in extent. A refinery has been built at Callao, but the recent war between Peru and Chili has caused a suspension of operations. The Peruvian oil does not yield any paraffine, nor a considerable amount of naphtha.

It is reported that in Bolivia the three principal springs of Cuarnzute, Plata, and Pignirainda form an oil stream 7 feet wide. (a) This wonderful story lacks confirmation.

ENGLAND.—In reply to a letter of inquiry in relation to the occurrence of petroleum in England, E. W. Binney, F. R. S., the distinguished geologist, wrote, November 14, 1881, as follows:

I am in receipt of yours, wherein you ask me if petroleum has been found in quantity in Great Britain. It was found about one hundred years since in making the Duke of Bridgewater's tunnel at Worsley, at Wigan and West Leigh in the Lancashire coal-fields, at Coalbrookdale and Wellington in Shropshire, and Riddings in Derbyshire, two other coal-fields; also in a peat bog at Down Holland, near Ormskirk, in Lancashire, but none to my knowledge in commercial quantities. The greatest supply that I have ever seen has not been more than 50 gallons a day, and even that soon diminished. When I went down Mr. Oakes' pit at Riddings in 1848 the petroleum came out of the black shale roof dripping, and not as a spring. The coal is a gas-coal in the lower part of the middle coal measures.

In a paper read before the Manchester Geological Society, March 30, 1843, Mr. Binney, in company with Mr. John Hawkshead Talbot, described the manner in which the petroleum occurred at Down Holland moss, northwest of Liverpool, on the north bank of the Mersey, near its mouth:

The whole of the moss is in cultivation either under the plow or in grass, and has been so for at least forty or fifty years, and all or the greater portion of it lies at a lower level than the high-water mark of the sea at Formby. On approaching the place where the peat containing petroleum occurs, from Down Holland, the authors soon became aware of its presence by an empyreumatic smell, resembling that yielded by Persian naphtha, and the water in the ditches was also coated with a thin film of an oily, iridescent fluid that floated upon its surface. In walking over some oat-stubble fields, and thrusting their heels through the black decomposed peat forming the soil, they felt a hard, pitchy mass, of 3 or 4 inches in thickness, which yields no smell unless it is burnt. On exposure to the atmosphere for a time the pitchy matter lost the greater part of its inflammability, and was finally converted into black mold. This substance also occurred under the roots of the grass in old sward fields, but it then yielded an odor similar to the petroleum that floated on the surface of the water, and pervaded the moist peat. (b)

I remember to have once met a lady who spent her childhood in New Hampshire, where she recollected a peat bog presenting similar phenomena to that above described.

Arthur Aiken, esq., in 1811, described the occurrence of petroleum in the great coal-field of Shropshire. He says the thirty-first and thirty-second strata are coarse-grained sandstone, entirely penetrated by petroleum; they are both together 15½ feet thick, and have a bed of sandy slate clay about 4 feet thick interposed between them. These strata are interesting as furnishing the supply of petroleum that issues from the tar-spring at Coalport. (c) In 1836 it was still further described by Dr. Preistwich, who says:

The well-known tar-spring at Coalport, which had its rise in one of the thick sandstones of the central series, formerly yielded nearly 1,000 gallons a week, but it now produces only a few gallons in the same time. In sinking a shaft at Priorslee the 20-yard rock was so charged with petroleum that the shaft was converted into a tar-well. It formerly yielded 2 or 3 gallons a day. In a pit at the top of the same dingle petroleum exudes in so great abundance from every crevice in the "little coal", and from the shale forming the roof, that the colliers are obliged in the latter case to have large plates of iron suspended over them. More rarely petroleum is found in cavities of the Pennystone nodules. (d)

Dr. Richard Bright described in 1811 a liassic limestone in the neighborhood of Bristol, containing "claws of crustaceæ, corallines, and millions of the stalks of encrinites. They were first noticed by Mr. Miller surrounding calcareous concretions in the black rock, which are penetrated with petroleum. Petroleum sometimes exudes from the rock in small quantity". (e) A correspondent of *Iron* describes, in 1875, the occurrence of petroleum in a coal

a *Deutsche Industrie Zeitung*, 1868, p. 400.

b Papers read before the Manchester Geological Society in 1842-'43, p. 17.

c T. G. S. (1), i, 195.

d T. G. S. (2), v, 438.

e T. G. S. (1), ii, 199.

pit at Longton, in North Staffordshire, the first discovery being made in a seam of coal that seemed to be saturated with it. Five or six tons a week are collected: a valuable addition to the output of coal. The coal is used for the manufacture of illuminating gas, and is rich in hydrocarbons. (*a*)

FRANCE AND SWITZERLAND.—There are three sections of France from which bitumen is reported. Petroleum floats on the water of springs, and the rocks in the neighborhood are saturated with bitumen at Saint-Boëz, Basse-Pyrénées; (*b*) it has not been found anywhere, however, in the Pyrenees in quantities commercially valuable. In the hills that skirt the highlands of Auvergne, at Gabian, near Béziers, petroleum is reported. At Ardèche and Autun asphalt occurs, and in the neighborhood of Alais and at Bastenne asphaltic limestones are obtained and used in large quantities in the preparation of the asphaltic pavement so largely used in Paris and other French cities. (*c*) The third district is in Savoy, and extends into Switzerland. In the Val de Travers the celebrated bituminous limestones of Pymont and Seyssel occur in the department of Ain. This asphaltic stone is not stratified, but is crossed with fissures in all directions, and consists of cretaceous limestone, calcareous schists, and molass, the latter a sort of asphaltic breccia. The porous limestones are saturated with bitumen, and the siliceous pebbles and fragments of the molass are cemented with the same material, as has been repeatedly proved on comparison. The limestone is quarried and pulverized and is then heated, and while hot it is thoroughly mixed with asphalt extracted from the molass by repeated boiling in water. This asphalt rises to the surface of the water and is skimmed off. The mastic thus prepared is used in enormous quantities in Paris and other French cities. A similar material is reported from the Tyrol, in eastern Switzerland.

GERMANY.—In Alsace, on the lower Rhine, at Schwabweiler, Pechelbronn, and Lobsan, petroleum has been obtained for many years and has been employed for local uses, but it has never been introduced into commerce. Several wells have been drilled at different points, and a small yield of oil has been obtained in some of them, but the enterprises, on the whole, were not remunerative. Petroleum is also reported near Carlsruhe, in the grand-duchy of Baden, but concerning it I have no particulars. In Hanover, on the Lüneburger heath, south of Hamburg and east of Bremen, the occurrence of petroleum has been known for at least a century. Since 1863 several attempts have been made to procure petroleum near Oberg by boring, and at different times, particularly within the last two years, the reports have been such as to encourage an expectation of a production rivaling that of Pennsylvania.

In 1876 it was stated that at Oberg the source of the petroleum was supposed to lie at a depth of 700 or 800 feet, and that it had been obtained at Edemissen and Oedessen by the re-establishment of mines having but a single shaft. In Kline Eidessen the sand is permeated with petroleum to such an extent that it is found on the water that collects in foot-tracks. At the village of Weitze, in the northern part of the district, is found an extensive stratum of sand of about 1,000 meters long, 600 meters broad, and 75 meters deep, which corresponds to 45,000,000 cubic meters, the upper strata of earth containing about 10 per cent. of petroleum. The owner of this tract, which has been penetrated to 125 feet, has often bored and obtained petroleum in a very primitive way through the gushing of oil from the sand. (*d*)

In March, 1880, a company was organized in Bremen for the purpose of deep boring, with the expectation of obtaining at greater depths than had hitherto been penetrated a lighter variety of oil, that previously obtained from wells 220 feet deep having had a specific gravity of 28°, and commenced operations on the southern border of the Lüneberger heath, at a point 25 miles east of Hanover, on the railroad to Brunswick. A refinery has been established at Peine, 20 miles from Hanover, and a pipe-line, has been laid from the wells.

Mr. William C. Fox, United States consul at Brunswick, reports that traces of petroleum have been found in belts or spots commencing in the village of Klein Schoppenstate, in the duchy of Brunswick, and running west in a direct line for 40 miles to the village of Wietze, on the river Aller, a navigable tributary of the Weser. Two of these belts are at present known: the Oelheim, near Peine, and another 8 or 10 miles to the northwest. The former contains about 25,000 acres, and embraces the villages of Edemissen, Odessa, Windesse, and Steterdorf.

At present, borings are confined to about 20 acres, and there are 12 pumping wells, yielding 1,250 barrels a week. A flowing well, struck last July, caused great excitement, the petroleum having a specific gravity of 0.888, and producing, when refined, about 40 per cent. of illuminating oil of very superior quality, 40 per cent. of lubricating oil, and 5 per cent. of naphtha. (*e*) For barreling, American barrels are preferred. While this field may be said to be one of the most promising fields, it cannot be said yet to promise any considerable competition with the fields of Pennsylvania.

DENMARK AND SWEDEN.—At Hölle, near Heide, in Ditmarschen, over an immense bed of petroleum, there is a layer of light diluvial sand 20 feet deep, saturated with tar, which may be cut like cheese. There is also found here an important bed of asphaltic limestone, similar to that of Seyssel. (*f*)

a San Fran. Min. and Sci. Press, xxi, 184.

b M. Thoré, L'année Sci. et Ind., 1872, p. 251.

c S. P. Pratt, Q. J. G. S., ii, 80.

d Archiv für Pharmacie, cclix, 461.

e Report, October, 1881.

f Dr. L. Meyn, J. S. A., xxi, 12.

At Nullaberg, in the northwestern district of Wermland, west Sweden, metamorphic strata of gneiss and mica-schist have been observed. Bituminous matter is distributed everywhere throughout the whole mass of these strata, so as to be present even in the smallest fragment, giving them a black color closely resembling gunpowder. (a)

ITALY.—Petroleum wells have been dug and bored along the southern borders of the valley of the Po, in the provinces of Voghera, Piacenza, Parma, Modena, and others, and in the provinces of Chieti, east of Rome, on the Adriatic sea, and of Caserta, on the gulf of Tarentum. Small quantities of petroleum have been obtained in these localities for centuries; also in the province of Girgenti, on the island of Sicily. Asphalt occurs at Marsicounova and in the valley of Pescara, and asphaltic schists or bituminous clay have been observed in many places in southern Italy.

Professor Silvestri described, in 1877, paraffines and homologous hydrocarbons, which he obtained in lava about 13½ miles on a direct line from the great central cone of Etna. (b) The gas-springs of the Apennines have been many times noticed as of scientific interest, but have never been made of economic value.

The petroleum interests of Italy have been for many years locally valuable, but do not promise to become of greater importance.

DALMATIA AND ALBANIA.—On the island of Brazzo, on the coast of Dalmatia, and also at Ragusa, on the mainland south of Brazzo, extensive deposits of asphaltum are reported. This island is nearly opposite the valley of Pescara, on the Italian coast.

Farther down the coast of the Adriatic lies the island of Zante, where a petroleum spring occurs in a marsh near Chieri that was mentioned by Herodotus in the fifth century before Christ. One well was drilled 300 English feet, and produced about half a hogshead daily, which progressively diminished; another was drilled later that at the same depth struck a black, hard, and fetid limestone; and another was at the side of the marsh, and struck oil at 70 feet, yielding 5,000 liters in seven hours. The latter afterward became completely sterile, and was abandoned, and borings made near the spring in 1865 were not successful. (c) On the mainland east of Zante lies the coast of Albania. There, in the neighborhood of Selenitza, occur some of the most extensive and remarkable asphalt deposits in Europe. Strabo remarks that "in the country of the Apolloniates there is a place called Nymphæum. It is a rock which emits fire, at the foot of which flows a spring of warm bitumen, which probably proceeds from liquefied bitumen, because on a neighboring hill there is a mine of bitumen, where, as related by Posidonius, the earth, from the excavations from which the bitumen has been exhausted, converts itself into that substance". (d)

Vetruvius also mentions the same springs, and says: "Around Dyrrachium and around Apollonia are springs which emit great quantities of pitch with water." (e) Durazzo, in Albania, occupies the site of the ancient Dyrrachium, and the convent of Pollina is built upon the ruins of Apollonia, both of which are found near the emboucheur of the Vojutza (Aous of the ancients), about six hours to the northeast of Avlona. "It appears that the curious phenomena which these springs manifest to-day arrested the attention of the Greek and Roman naturalists, because they are mentioned in the works of Aristotle, Pliny, Ælian, and Dion Cassius." (f) Setting aside some erroneous ideas, due to the ignorance of the ancients regarding natural phenomena, recent studies of the bituminous deposits of Epirus confirm in a remarkable manner the observations made by these early writers, and the testimony of more modern authors is less abundant and exact than that furnished by the ancient historians. Recently the bitumen from this section has been employed in Trieste, Naples, and Marseilles as a substitute for rosin in calking ships.

Between Durazzo and Avlona the coast of Epirus is level, and consists of plains formed by the alluvium of the rivers Usoli Komobin (Senussus of the ancients), Beratino (Apsus), and Vojutza (Aous), which drain Albania throughout its length, and which have their sources in the high mountains of Macedonia. It is in the hills at the foot of these precipitous and almost inaccessible mountains that the deposits of asphalt occur in great variety of detail. M. Coquand, to whose elaborate article I am mainly indebted for the facts here stated, (g) regards the exploitation as very rude and of very great antiquity, probably extending from a period long prior to the Christian era to the present time, but destitute of any general system. This want of method, while compromising the future interests of the deposit, has opened it up at many points, and has admirably exhibited the manner in which the mineral lies in the formation. It is easy to perceive that it does not lie in regular beds or veins, but in irregular masses in the midst of sandstones and conglomerates, of the form of which no general description will give an idea, except that a sort of parallelism may be observed among them, and that each mass consists essentially of a central portion of considerable thickness, which gradually thins out in all directions to zero. In no case does the bitumen penetrate the roof above the mass, but was evidently injected from below. The following illustration (Fig. 2) shows at a glance a deposit that has furnished an enormous quantity of bitumen. A depth of 3 meters (9.84 feet) is not rare

a L. J. Englestrom: *The Geological Magazine*, iv, 160.

b *Gazetta Chimica Italiana*, vii, 1; B. D. C. G., 1877, 293; C. N., xxxv, 156.

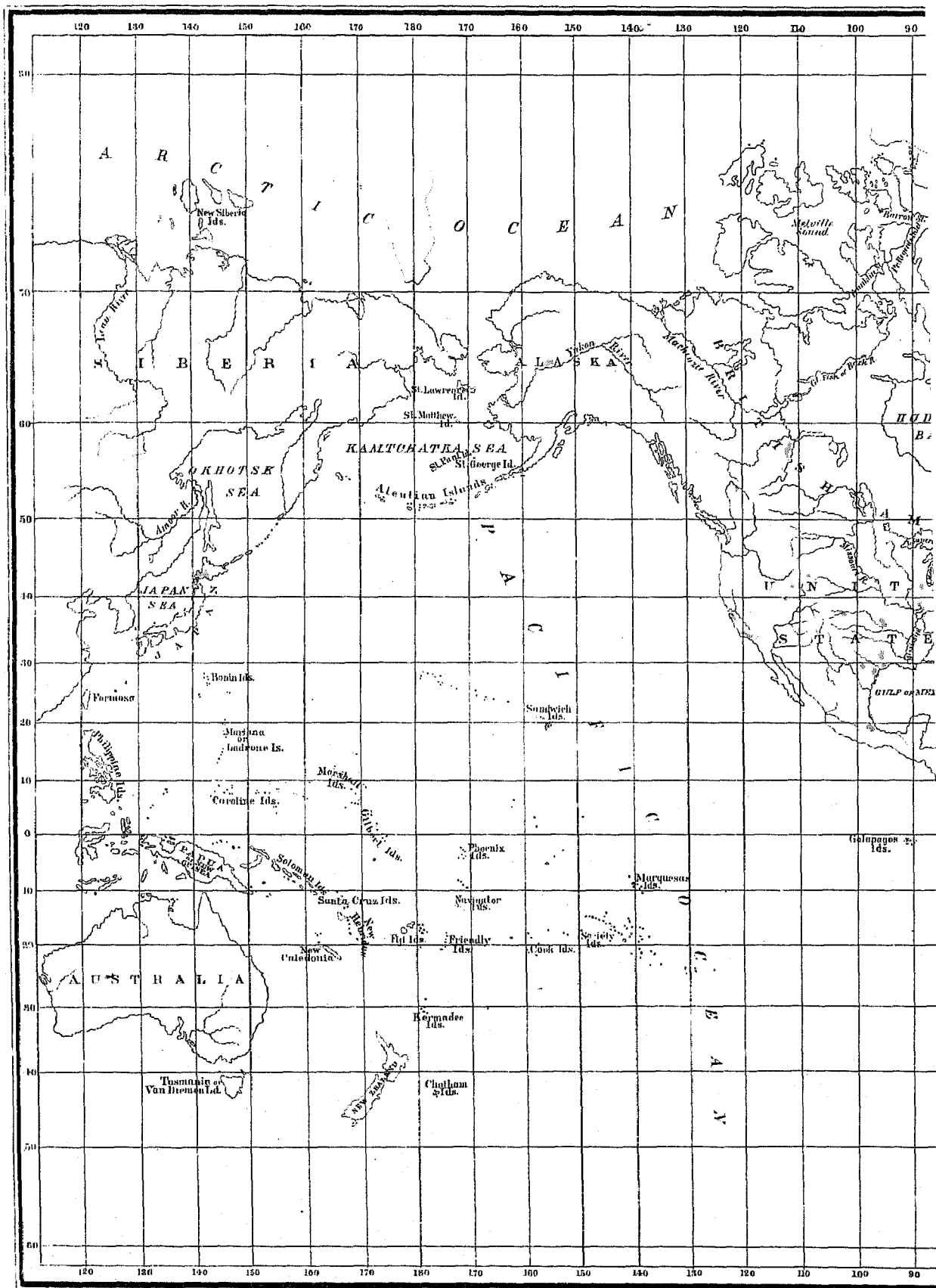
c *Les Mondes*, October, 1865.

d B. S. G. F., xxv, 20. Translated from French rendering.

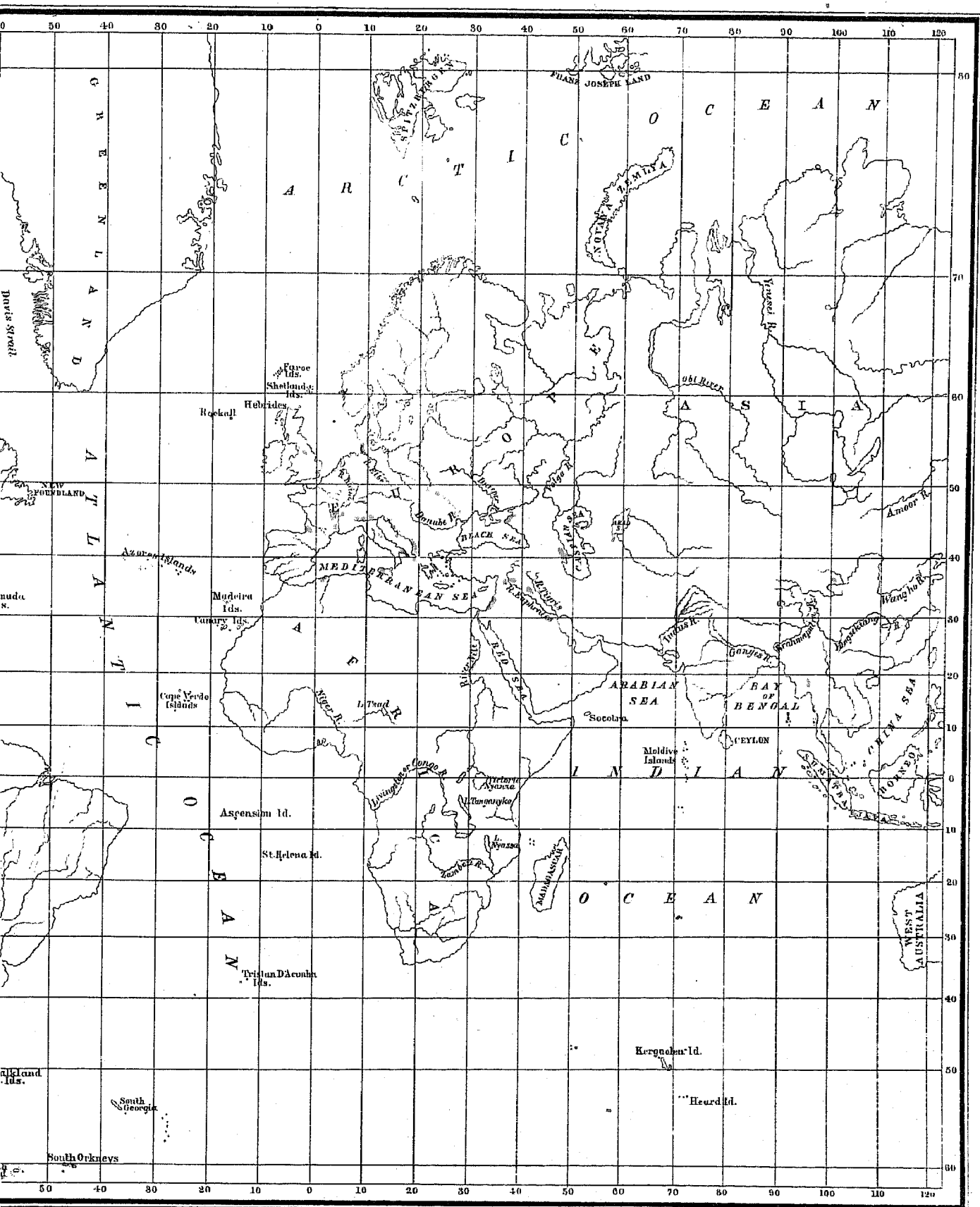
e *Ibid.*

f This passage and the others given above can be found in the original in *Bul. Soc. Géo. de France*, xxv, 20.

g B. S. G. F., xxv, 20.



Map showing the Dist



Bitumen throughout the World.

in the thickest places. The bitumen is almost always of very great purity, and generally consists of compact, very homogeneous masses, very black, brilliant, tarnished upon the surface, very friable, with a resinous fracture, softening by percussion or heat, and with a pronounced asphaltic odor.

The ancient workings have caved in, making their exploration no longer possible. It appears, to judge by tradition, and, above all, from the ancient workings, now overgrown with oaks many centuries old, that the exploitation reaches back to a time anterior to Strabo; because we read in that author that, following Posidonius, the bituminous earth, which he calls *ampelites*, was a remedy against the worms that eat the vines, the worms by this means being destroyed before they had ascended the trunk to the young sprouts. This method appears to have been practiced until lately, and perhaps it is to-day, because the greater part of the bitumen of Albania was exported to Smyrna, where it was used for the preservation of vines, and more frequently for the calking of ships.

Some of the springs of water rising from the formation containing the bitumen of Albania are accompanied with maltha, but in insignificant quantity.

ROUMANIA.—The Roumanian oil-fields lie in the northeast part of Wallachia and the southern part of Moldavia, in the valleys of the streams that drain the eastern slopes of the Siebenbürgen.

The Wallachian oil district lies on the southern slopes of the Transylvanian Alps, and is more extensive than that of Moldavia. The wells are from 6 to 12 miles north of Plojeshti, a station on the Roumanian railroad. In Bakoin the inhabitants use the inflammable gas which issues from the ground to cook their meals. The manner of obtaining the oil is very primitive, the wells being dug as for water, the landlord receiving a tenth of the net produce as rent. A part of the crude petroleum is refined at Sarati and Plojeshti, and part is sent by rail to Vienna, Pesth, and Odessa.

The Moldavian petroleum fields occupy a triangle bounded by the rivers Taslen and Trotusch, not far from Adschud station, on the Roumanian railroad. The wells near Morneshti do not exceed 120 meters (394 feet); those near Salante and Comonesti 50 to 70 meters (164 feet to 230 feet) in depth. Like the Wallachian wells, they are worked in the most primitive manner, and the proprietors here receive as rent one-third of the gross produce. The cost of the petroleum at the well's mouth does not exceed 4 francs per 100 kilograms (20 cents per 220 pounds).

The Moldavian petroleum is darker than that of Galicia, and remains fluid at a temperature of 20° Celsius—4° F. (a)

GALICIA.—Petroleum is found in many localities on the Hungarian side of the Carpathians, but its exploitation is of little or no importance. In Galicia there are three principal localities that yield petroleum and ozokerite: the region around Sandecer, in west Galicia; that around Bobrka, near Dukla, in middle Galicia; and that around Boryslaw, in east Galicia, and Basco, on the confines of Moldavia. This region is said to be in general outline 400 miles long by 40 miles wide. Although ozokerite is found associated with petroleum wherever it occurs in both Galicia and Roumania, its production is principally confined to the east Galician district, in the neighborhood of Boryslaw and Stanislaw. It appears from statistics that I have met with that the fields of east Galicia were at first much the most important; but while the total production of Galicia has decreased, the relative production of west Galicia has increased. The exploitation has been conducted in a very rude manner, largely by Polish Jews, who occupy that country, and all attempts at innovation by the introduction of machinery, both for boring and for refining, have been resisted with great pertinacity.

The development of oil territory by shafts has been encouraged by the amount of ozokerite that almost everywhere accompanies the oil and that cannot be obtained by other methods of exploitation. Wells have been bored, however, which in some instances have been productive and in many others have failed. The great importance of the ozokerite industry, which will be referred to in detail in a subsequent chapter, will prevent the complete substitution of borings for shafts.

RUSSIA.—Petroleum is reported to have been observed in northern Russia, in the province of Archangel, on a streamlet that runs into the river Betchora; also at "some distance from Orenburg", on the Ural river, but the exact locality was not given.

In official reports the Russian petroleum fields are divided as follows:

Government of Tiflis.—Mirsanski, Schirorski, Eldarski.

Government of Baku.—Bakinski, Derbentski, Kaitags-Tabarsaranski.

Kuban district.—Kadygenski, Kudako.

Terek district.—Gronenski, Maisha-Kajevski, Karabulakaki, Brajimavski, Benojevski.

Daghestan.—Berikaki, Djernikentaki, Nafutanski, Bashlinski, Tupsu-Kutanski, Ghiak-Salgav, Kukinski, Napkutanski.

A reference to map I will show that these districts are embraced in a triangle, the apex of which is at the mouth of the Kouban river, near the entrance to the sea of Azof, extending eastward to the Caspian sea, and embracing that portion of its western coast lying between the mouths of the rivers Terek and Kura, and embraces the flanks of the Caucasus and the valleys of the principal rivers that drain them. There are also indications of petroleum across the Crimea that have attracted some attention.

The Kouban oil-fields proper begin at Taman, situated on the strait which connects the Black sea with the sea of Azof, and extends along the foot-hills of the western extremity of the Caucasus mountains to the river Balah, a distance of about 250 miles.

^a Dr. H. E. Ginth, *Oester. Monatschrift f. d. Orient*, 1878; John Fretwell, jr., J. S. A., xxvi, 481.

The Apscheron oil-field as at present worked lies within a radius of 20 miles of the city of Baku; but the larger portion of the oil has been obtained at Balachany, 12 miles north of Baku, where naphtha has been produced from the most ancient times, and from Sabonutchi, which was explored in 1873. This first part contains (1880) forty-seven wells, of which twenty-eight are productive, yielding 6,192,000 pounds daily of an average specific gravity of 0.8675, while the second part yields 6,622,000 pounds per day of the specific gravity of from 0.820 to 0.860. The specific gravity is very variable in the same well, and in general diminishes with the depth, being greatest near the surface, from loss of gas. The light oil contains volatile products of a specific gravity of 0.62, of which no use is made. The illuminating oil varies from 15 to 85 per cent., the average being between 35 and 40 per cent. (a) On the outskirts of the field a colorless oil is obtained that can be burned without refining. This oil soon thickens and becomes asphalt.

The oil seems to lie in a sort of quicksand, irregularly interstratified with clay, as fine, loose sand rises with the oil and collects around the wells so that it has to be shoveled away. This oil has been known to spout from an 8-inch hole from 50 to 60 feet high; yet there is no regular stratum of sand yielding the oil, and no particular depth at which it may be struck. One well in the Kouban yielded oil of 46° at from 8 to 10 feet in depth. This oil does not contain paraffine.

The Bebeabat field is below Baku on the coast of the Caspian sea, and produces oil resembling that of Baku; but it deteriorates by keeping, and is often run up on a salt lake near by and set on fire. On the island of Tekillekin, or Naphtha island, on the eastern shore of the Caspian sea, a well was drilled which produced a small quantity of oil of a better quality than that of Baku, and one well at about 140 feet yielded oil, and at 200 feet yielded hot water. Ozokerite and "living earth", which is a mixture of soft asphalt and pulverized shells, abounds along this shore. (b)

The Caspian sea is dotted with numerous islands, which produce yearly a large quantity of naphtha (petroleum), and it has been no uncommon occurrence for fires to break out in the works and burn for many days before they could be extinguished. In July, 1869, owing to some subterranean disturbances, enormous quantities of petroleum were projected from the wells and spread over the entire surface of the water, and, becoming ignited, notwithstanding every precaution, converted the sea into the semblance of a gigantic flaming punch-bowl many thousands of square miles in extent; but the fire burnt itself out in about forty-eight hours, leaving the surface of the water strewn with the dead bodies of innumerable fishes. Herodotus mentions a tradition that the same phenomenon was once before observed by the tribes inhabiting the shores of the Caspian sea.

There is practically no limit to the amount of oil to be obtained at Baku, but with the exception of the Caucasus-Carpathian region the petroleum production of Europe is only of local importance. The production of maltha is insignificant, but the deposits of asphaltum and asphaltic limestone are of great and increasing importance. No region except the Caucasus has made any approach to rivalry in European markets with the petroleum products of the United States.

ASIA MINOR.—Many of the localities furnishing bitumen in Asia are extremely difficult to locate with exactness; but gas-springs are said to occur on the coast of Karamania, (c) which is that portion of Asia Minor bordering the northeast portion of the Mediterranean sea. Bitumen is also reported in Armenia near Lake Baikal, and in southern Siberia near Derabund; (d) asphaltum near Iskardo (e) and near Cashmere; petroleum in Assam (f) and Pegu; (g) also near Kohat. (h) Gas-springs accompanying mud volcanoes are also reported in Kerman. (i) The authorities for these localities are nearly all to be found in works published in India, to which I have not had access.

"The asphalt of the Dead sea and its vicinity has been noticed by Strabo and other ancient writers, and many conjectures have been made by both ancient and modern authors respecting its origin. It seems to be a well-established fact that the asphalt rises in such large masses during or after earthquakes as to remind one of islands floating on the sea. While this asphalt, having a density of 1.1040, floats on the water of the Dead sea, which has a density of 1.1162, it would sink in the water of the ocean. The rocks in the neighborhood of the sea are often bituminous cretaceous limestones, containing a large quantity of asphaltic material. This is particularly to be observed in several of the ravines that border it, where the dolomitic limestones are highly charged with bitumen, and, being broken up and carried down into the sea by the winter torrents, the bitumen becomes disengaged, and is cast upon the shore." (j)

In one of these ravines, on the eastern borders of the sea, M. Lartet describes pebbles of siliceous cemented into a pudding-stone by bitumen and stalactites of asphalt produced by the liquid bitumen slowly dripping from the bituminous cretaceous limestones. This, too, is washed into the sea and cast on shore. The amount received by the sea in this manner, however, is not sufficient to account for the islands of bitumen seen floating on the surface. (k)

On the western border of the valley of the Jordan similar deposits occur at the same level, and in many localities throughout Judea and Arabia Petraea from immemorial periods asphalt and maltha (slime) have been obtained from springs and shallow pits.

a M. Goulichambaroff, *Jour. Rus. Phys. and Chem. Soc.*, xii, 5; *Nature*, xxiii, 42.

b Communication from J. R. Adams, of Oil City, Pennsylvania to S. F. Peckham.

c Beaufort: *Survey of the Coast of Karamania*, 1820.

d G. T. Vigne: *Rock Oil*, near Derabund, Kabul 1842.

e G. T. Vigne: *Travels in Kashmir and Little Tibet*, 1842.

f Report Geo. Surv. of India, I, pt. 2, p. 55.

g Lt. Duff: Pegu oil gas. *Jour. As. Soc. Bengal*, 1861.

h E. Thornton: Oil-spring near Kohat, *Gazetteer of India*, 1862.

i H. Pottinger: *Petroleum of Kerman*, 1840.

j Lartet, B. S. G. F., xxiv, 12.

k Ibid.

Deposits of bitumen have been described as occurring near Zaho, in Kurdistan, 440 miles above Bagdad, on the Tigris. From the description I should conclude that this material is asphaltum. It was used successfully in 1874-75 on the steamer Mosul for making steam, and also for the manufacture of gas. Several other outcrops of bitumen occur nearer Bagdad, and liquid petroleum occurs at many points upon the road from Ribamich to Bagdad, and also between Bagdad and Mosul, in the valley of the Tigris. (a)

PERSIA.—Persia abounds in bitumen springs, which have been noticed and described by travelers and historians from Herodotus to the present time. One of the most noted springs of water yielding bitumen is situated five German miles from Suza, at Ardericca. Others are located on the plateau of Iran, near Durr, in the valley of of Jerabi, and also at Chusistan, not far from a volcano that was active in the second century. The bitumen wells Kerkuk or Tuzkurmati, four days' march southward from Arbela, are also celebrated. They may be known at a great distance through their odor, their sulphur vapor producing headache, on which account they are unendurable in summer time. Other localities of minor importance in the mountains that separate Persia from Kurdistan and the valley of the Tigris are mentioned. The naphtha springs of Van Kalesi were inclosed in the walls of a castle, where they flowed from a niche. Another castle is described as belonging to Sassanite times, situated upon a crag above a naphtha spring that was arched over with great blocks of freestone—perhaps from very ancient times.

Bitumen in its various forms has been used in the valley of the Euphrates and adjoining regions from the earliest times. (b)

HINDOSTAN.—Natural gas furnishes the material burned in a number of Hindoo temples in Thibet and northern India. Petroleum wells are reported in Cashmere and Thibet, but I have been unable to learn anything concerning their exact localities. A locality occurs in the Punjab that has attracted some attention, but it has not yet been proved to be of importance. It lies in the corner between Cashmere and Cabul, and is nearly 100 miles by 90 in extent, being mostly between the Indus and Jhelum, in what is called the Sind Sagur Doab (two rivers), and is mainly in the mountainous or hilly part (Kohistan) of the Doab. The oil-springs are in the northern slopes of the Salt range that lie upon the southern border of this region, or in the Choor hills that lie upon its northern border. Oil, maltha, and asphaltum occur at these springs. Borings have been made at Gunda, and yielded at first 50 gallons a day, which gradually decreased. This oil is dark-green in color, is of a specific gravity of 25° Baumé, and has been used by the natives for burning with a simple wick, resting on the side of an open dish. (c)

BURMAH.—In a letter from Rev. J. N. Cushing, dated Toungoo, September 14, 1881, appears the following in relation to the wells in this country:

There are only two places in all Burmah where petroleum is produced to any extent, viz: Arracan and Yenangyoung, in upper Burmah. The production of the wells in Arracan is very small. Within a few years a company has been formed to work them as an experiment, but I have never seen any statement of the results, and think they must be inconsiderable. Yenangyoung (Earth-oil river) is a large town on the Irrawaddy about 400 miles north of Rangoon, and the oil-wells lie about 3 miles east of the town, among some low and very barren hills, the chief vegetation of the unproductive soil being several varieties of cactus. There seemed to be a good deal of light, soft, sandstone, through which here and there ran layers of a dark rock resembling granite. The roads were in some places worn into the hills to a depth of 10 feet, the fierce torrents formed during the rain washing out all loose soil.

When I visited the wells they were about 200 in number, although some were not yielding oil. These were upon ground as highly elevated as any, and occupied an area of about 100 acres. They were of various depths, the deepest being about 160 cubits (240 feet). I do not think that the number of wells has greatly increased since my visit, for before that petroleum had been found only in that locality, although search had been made for it in adjacent localities. What might be found by the skilled labor of the far West using the scientific knowledge which gives it success I do not dare to say.

CHINA.—There do not appear to be any wells in China that are made for the purpose of procuring petroleum; but from the communications made by M. Imbert to the French Academy, and also by L'Abbé Huc, it appears that petroleum is obtained in wells bored for salt, as it often is in this country, and that the oil is often accompanied by inflammable gas. The Chinese call the latter Ho-tsing (fire-wells), and use the gas for a variety of purposes, such as boiling brine and for domestic fuel, the gas being conveyed long distances in bamboo tubes, terminating in a clay or porcelain burner. In his *Travels in the Chinese Empire*, chapter vii, L'Abbé Huc says:

When a salt-well has been dug to the depth of a thousand feet, a bituminous oil is found in it that burns in water. Sometimes as many as four or five jars of 100 pounds each are collected in a day. This oil is very fetid, but it is made use of to light the sheds in which are the wells and caldrons of salt. The mandarins, by order of the prince, sometimes buy thousands of jars of it, in order to calcine rocks under water that render navigation perilous.

Specimens of this petroleum sent to France were submitted to a committee of the French Academy for examination. (d)

The wells are described by L'Abbé Huc as occurring in the province of Sse-tchouen, which is the largest province of China, and borders upon Thibet. Petroleum is also reported from the northern province of Shansi.

a L. Mongel: *Ann. des Mines* (7), vii, 85; *Proc. Inst. of Civil Engineers*, 1875, p. 307.

b Ritter's *Erdkunde*, ix, 147, 177, 519, 555; xi, 191; x, 142.

c B. S. Lyman, *Trans. Am. Phil. Soc.*, xv, 1.

d *Comptes-Rendus*, xxii, 667.

JAPAN.—The petroleum fields of Japan lie in the southern part of Yesso and the northwestern part of Nippon, and have already been noticed in chapter I, page 17.

JAVA.—Mineral oils are found in many of the islands of the Indian archipelago, and are there known under the name of Minjak Lantoeng at Java, or Minjak Linji at Sumatra; and as they are much used by the natives, they are regularly collected and sold in the markets of the principal villages and towns. The localities where these oils rise spontaneously in natural fissures or artificial excavations are ordinarily surrounded by warm or saline mineral springs.

A specimen of oil from Palantoengan, in the residency of Samarang, has the consistency of tar and a density of 0.955 at 16° C. A specimen from Tjiakijana, in the district of Porbolingo, in the residency of Banjoemas, is as liquid as water, with a deep green color by reflection, and has a density of 0.804 at 16° C. Spontaneous evaporation produces a mass of the consistency of yellow butter; distillation yields 40 per cent. of paraffine. (a)

Von Baumhauer, the distinguished chemist, examined and reported upon six specimens of petroleum from as many different localities in the Dutch East Indies: from Amönchay, in Borneo; Bodjoinegoro, in Rembang; Madjalengka, in Cheribon; in Soerabaga; Lematang-Iir, in Palembang, Sumatra; and Iliran and Banjoesin. His examination shows that the petroleum of Rembang and Cheribon are of very excellent quality, while the others are of a viscous consistency. He remarks that petroleum in this region is very abundant, and is easily obtained at a depth of 250 meters (820 feet), and recommends boring, considering the oil as of great importance to the country. (b).

AUSTRALIA.—Petroleum is reported as occurring in Australia and New South Wales, and crude paraffine near Gisborne, in New Zealand.

AFRICA.—Petroleum is reported from Egypt, as examined by Frederick Weil, with a density of 0.953, but on distillation it did not yield naphtha or illuminating oil with a density of 0.800. It was considered a superior lubricator, and is especially adapted to heating marine boilers and in the manufacture of gas. (c) It is also reported as having been discovered in Algeria, in the Dahra-oraisaïc, the region occupied by the tribe of Beni-Zarouel, in that part of the chain that overlooks the plain of Chiliff. A spring of glutinous petroleum here indicates a suitable place for exploitation, the product having the ordinary properties of maltha. (d) A more complete examination of Africa will doubtless reveal other localities which yield bitumen.

An examination of map I will show that bitumen occurs on the American continent along a line extending from Point Gaspé, in Canada, to Nashville, Tennessee, and in Europe-Asia along a line extending from Hanover, on the North sea, through Galicia, the Caucasus, and the Punjab. These are the principal lines. In America it also occurs on the Pacific coast from the bay of San Francisco to San Diego; again from northern Nebraska to the mouth of the Sabine river, on the Gulf of Mexico; again from Havana near the western end of Cuba, through San Domingo and the circle of the Leeward and Windward islands, to Trinidad; thence westward on the mainland to the Magdalena river, and southward from that point to cape Blanco, in Peru. In Europe-Asia bitumen occurs on the lower Rhine and in the valley of the Rhone; from northern Italy, following the Apennines, to southern Sicily; along the eastern shores of the Adriatic, through Dalmatia and Albania, into Epirus; again along the depression in which lies the Jordan and the Dead sea; again along the mountains that border the valley of the Tigris in the east; again from western China through Burmah, Pegu, Assam, Sumatra, and Java; and lastly in Japan. It will be observed that these lines are for the most part intimately connected with the principal mountain chains of the world.

a Bleekrode, Rep. de Chem. Appl.; C. N., v, 158; *Le Technologiste*, xxiii, 402.

b Arch. Neerland, iv, 299; Mon. Sci., 1870, p. 53; W. B., 1878.

c Mon. Sci. 1877, p. 295.

d *Les Mondes*, xxxvi, 318.

CHAPTER III.—THE GEOLOGICAL OCCURRENCE OF BITUMENS.

SECTION I.—GENERAL CONSIDERATIONS.

The relation of geology to the occurrence of bitumens has been very liberally discussed during the last half century. In attempting to review the literature of this subject one is impressed with the fact that for the most part the opinions expressed may be said to be *provincial*, inasmuch as they are based on observations made over a comparatively limited area, and from these limited observations generalizations are often made to include all of the varied conditions under which bitumen occurs in different parts of the world. My intention has been to compile this chapter from the papers of professional geologists who have directed their attention to the subject, and it is while attempting this work that the provincial character of the materials that I have to compile and the great lack of uniformity of opinions among eminent geologists who have written upon the subject have been most forcibly impressed upon me. Again, when comparing the earlier and the later authors, there is a lack of uniformity in nomenclature that renders the task of one seeking information extremely difficult. Deposits of bitumen in different parts of the world have been described by persons whose knowledge of geology is often of an extremely elementary character, yet almost every author who has mentioned a tar or petroleum spring endeavors to inform his readers respecting the age of the rocks from which it issues and discusses the origin of bitumens.

A clearer comprehension of the geological occurrence of petroleum can be had without particular reference to the political divisions of the earth's surface, and I shall therefore consider the subject only with reference to geological sequence. It has been frequently remarked that petroleum occurs in all geological formations from the Silurian up to the Tertiary, and while this is true as a general statement, it is misleading, for bitumen is not uniformly distributed through all formations, but occurs principally in two epochs of geological history, the Silurian and the lower half of the Tertiary. The vast accumulations along the principal axis of occurrence in the western hemisphere are found in Silurian and Devonian rocks; but the most productive axis in the eastern hemisphere lies in the Eocene of the Carpathians and the Caucasus. An examination of the geographical occurrence of bitumen east of the Mississippi river shows that it has been reported from localities which describe an ellipse upon the border of the Cincinnati anticlinal, which is really an elevation of Silurian rocks extending from central Kentucky to lake Erie, with Cincinnati nearly in its center, and sloping beneath the newer formations in all directions. Starting with Great Manitoulin island on the north, petroleum is reported at Port Huron, Michigan; Chicago, Illinois; Terre Haute, and in Crawford county, Indiana; Henderson, Cloverport, Bowling Green, and Glasgow, Kentucky; and in the region around Nashville, Tennessee, extending southeast to Chattanooga, where the Silurian rocks again reach the surface. Turning northward, the line extends almost unbroken from Burksville through the eastern counties of Kentucky into Ohio and West Virginia, and into Pennsylvania and New York, but how far has not yet been determined. The ellipse is completed by the petroleum fields of Canada. A portion of this territory is covered with the carboniferous formation, beneath and within which petroleum has often been found.

At Great Manitoulin island petroleum was obtained in the Trenton limestone. At Chicago and at Terre Haute the drill penetrated the Niagara limestone before reaching oil. The failure of the wells to reach oil in southern Indiana is attributed by Professor E. T. Cox to the fact that they were abandoned before they reached the carboniferous and the Niagara limestones. (a) Professor Shaler appears to regard the great Devonian black shale as the source of the oil of Kentucky. (b) The oil in that state is found saturating sandstone at Glasgow, and in crevices at Burksville and other points on the Cumberland, in many instances, as I am informed by those who reside in that vicinity and are familiar with the subject, beneath the black shale. In the neighborhood of Nashville, where the Lower Silurian rocks reach the surface, petroleum occurs within geodes that are inclosed within the solid mass of the blue limestone under such circumstances as to admit of no question as to whether the oil originated in the rock where found. As the occurrence of petroleum is studied in localities lying northeast of Nashville, the present location of the oil is found to be in rocks that lie in a continually ascending series. Around Burksville it is found in crevices, in a so-called marble in the Upper Silurian, immediately beneath the Devonian black slates. Further north it lies in the Devonian and subcarboniferous sandstones, and is held in the region in Johnson county partly in rocks that are now above the drainage level of the country. (c) In Professor J. P. Lesley's elaborate report upon this region he says: "A conglomerate age or horizon of petroleum exists; this is the main point to be stated." (d)

Leaving Kentucky and entering Ohio, we find the so-called oil break of West Virginia and Ohio furnishing petroleum in sandstones that lie within the coal measures. Still further to the northeast, in Pennsylvania and New York, the oil sands are all found beneath the coal measures in the Upper Devonian, and in Canada they again descend to the Lower Devonian.

a *Geological Survey of Indiana*, 1872, p. 139. b *Geological Survey of Kentucky*, N. S., iii, 107. c Lesley, P. A. P. S., x, 33. d *Ibid.*

At Belden, Ohio, the oil is found in crevices in the Berea grit which covers a wide expanse of country Lorain and Medina counties.

At Mecca, in the neighborhood of Power's Corners, the oil saturates the Berea grit, which lies within 80 to 100 feet from the surface. Water is pumped from the wells, bringing the oil with it. These wells are often used for water at the same time that they yield petroleum.

The geology of the trans-Mississippi localities producing petroleum has never been studied in any comprehensive or satisfactory manner. Professor G. C. Swallow says the petroleum of western Missouri and eastern Kansas comes from the coal measures, the well in La Fayette county, Missouri, passing through "sandstone, shale, coal, a limestone", and Professor Aughey reports the oil in the well at Ponca, Dixon county, Nebraska, as coming at a depth of 570 feet from the Lower Carboniferous. "The boring passed through the Cretaceous (Dakota) group, then through the Upper Carboniferous into the Lower Carboniferous, and obtained only a very small quantity of oil." Mr. S. F. Emmons says: "It (petroleum) exists in the Cretaceous rocks which extend along the eastern slope of the Rocky mountains from British Columbia to Mexico, and in many of the interior valleys." The outcrops mentioned in the last chapter as occurring in Wyoming and Colorado arise probably from the Cretaceous. I have no information respecting the geology of the outcrops in Texas.

The bitumen of the Pacific slope of Mexico, the West Indies, and South America is doubtless Tertiary Miocene in California and Eocene in Trinidad. In England the small quantity of petroleum that has been observed has sprung from the coal measures. In the valley of the Rhone and Savoy the bitumen is in Jurassic limestone. The bitumen of the Apennines, of Dalmatia and Albania, issues from rocks that are Eocene; also that of Roumania, Galicia, and the Caucasus. But little is known respecting the geology of the bitumen of Syria, Judea, and Persia. The Punjab is Eocene, and the little that is known of the deposits yielding petroleum in Burmah and the East India islands indicates that they are of the same age.

From these statements it will be seen that there is a vast area in the valley of the Mississippi, estimated at 200,000 square miles, over which petroleum has been obtained, the formations of which are nowhere newer than the coal measures. Another vast area, extending from California through Mexico to Peru, and including the West India islands, yields petroleum from Tertiary rocks, while on the eastern continent a belt of country extends from the North sea to Java, the bitumen-bearing rocks of which, so far as is known, are Tertiary. I shall have occasion to refer to many of the details of these localities in the fifth chapter. At present the bulk of the petroleum produced issues from rocks older than the Carboniferous, while the formations in by far the greater number of localities yielding bitumen are of Eocene age.

SECTION 2.—THE GEOLOGICAL OCCURRENCE OF PETROLEUM IN EASTERN NORTH AMERICA

The geological occurrence of petroleum in the United States has been discussed with reference to whether it has all primarily issued from the Silurian limestones and has accumulated in the crowns of anticlinals. This view has been forcibly argued by Professor T. Sterry Hunt, of Montreal. The question has also been discussed with reference to whether petroleum, having originated in deep-seated strata, has not collected in crevices which have resulted from faulting and movement of the overlying strata. The late Professor E. B. Andrews was perhaps the leading exponent of this view. Again, it has been urged that the oil, having originated in the lower rocks of deeply-seated strata, is held neither in crevices nor beneath the crowns of anticlinals but by capillary attraction in the interstices and cracks of porous sandstone. This view has been advocated by Professor J. P. Lesley. Dr. Hunt observed in Canada, Professor Andrews in West Virginia, and Professor Lesley in Pennsylvania and Kentucky, and from a careful examination of the facts to be observed in a summer's trip through the oil region from Olean, New York, to Nashville, Tennessee, and also from a careful collation of statements made by many oil producers and others, I conclude that each of these gentlemen is correct as regards his own locality. There is no question but that petroleum has originated in the Silurian rocks, and that the finding of oil in the Niagara limestone at Chicago and at Terre Haute was a strong confirmation of the opinions expressed by Dr. Hunt in his famous essay on the history of rock-oil, when he says, referring to a previous paper reported in the *Montreal Gazette*:

I asserted that the source of the petroleum was to be sought in the bituminous Devonian and Silurian limestones. Beside the carboniferous limestones (Devonian), we have shown that both the Niagara and Trenton (of Upper and Lower Silurian age) contain petroleum. (a)

There is no question that petroleum occurs in West Virginia along an anticlinal, as has been advocated by Professor Andrews. The hypothesis that petroleum occurs in huge fissures or cavities which have been represented by sections, in which water, oil, and gas are arranged according to their specific gravities, has not been sustained by later and more careful study of the subject. It is beyond question that the oil of Pennsylvania does not occur beneath anticlinals, nor in crevices, nor is it anywhere near the Silurian limestones; yet there is no doubt that at Gaspé and in Ontario the springs of petroleum occur along the crests of gentle anticlinals, as so carefully described by Dr. Hunt.

a C. N., vi, 5, 16, 35; C. Nat. (1), vi, 245; A. J. Ph. (3), x, 527.

In 1867 Professor C. H. Hitchcock contributed an article to *The Geological Magazine*, which has been very widely quoted, particularly as to the conclusions therein reached. These conclusions appear to have been obtained from a collation of the writings of Professors Hunt, Andrews, and Lesley; (a) and an address given by Dr. Hunt at a meeting of the Société Géologique de France, in which he made a general application of his views, based on his Canadian experience, to the occurrence of petroleum in the United States, appears to have been very widely quoted in Europe. (b)

In the article above mentioned Professor Hitchcock enumerates fourteen different formations from which petroleum has been obtained in North America (exclusive of the West Indies), and generally in commercial quantities. These are:

- a. Pliocene (c) Tertiary of California. This has been known for a century.
- b. Cretaceous in Colorado and Utah, near lignite beds. Not yet explored.
- c. Trias of North Carolina and Connecticut, in small amounts. (d)
- d. Near the top of the Carboniferous rocks in West Virginia. Most of the producing wells of this state are from this horizon.
- e. Shallow wells near Wheeling, West Virginia, and Athens, Ohio, not far from the Pittsburgh coal.
- f. Four hundred and twenty-five feet lower, near the Pomeroy coal-beds.
- g. At the base of the coal measures, in conglomerates or millstone grit.
- h. Small wells in the Archimedes limestone (Lower Carboniferous) of Kentucky.
- i. Chemung and Portage groups—certainly three different levels—in western Pennsylvania and northern Ohio.
- j. Black slate of Ohio, Kentucky, and Tennessee, or the representatives of the New York formation from the Genesee to the Marcellus slates. This is near the middle of the Devonian.
- k. Corniferous limestone and the overlying Hamilton group in Canada-West, extending to Michigan. This is largely productive.
- l. Lower Helderberg limestone at Gaspé, Canada East. This is Upper Silurian.
- m. Niagara limestone near Chicago, and awaits development. (e)
- n. In the equivalents of the Lorraine and Utica slate and Trenton limestone of the Lower Silurian in Kentucky and Tennessee. One well in Kentucky in these rocks was estimated to have yielded 50,000 barrels. (f)

Developments since 1867 have added little, if anything, to the above as a general statement. With particular reference to the three localities in Canada, Pennsylvania, and West Virginia, which practically yield the petroleum product of North America, I shall endeavor to show the manner in which nature has stored and yields such vast accumulations of material, and to present the ascertained facts without bias for any theory. Dr. Hunt has been a frequent contributor to the literature of this subject during the last twenty years, and from his articles in the *American Journal of Science* for March, 1863, (g) and November, 1868, (h) I make the following extracts, which embody his views upon the geological occurrence of petroleum in Canada:

The natural oil-springs which occur in various parts of western Canada are upon the outcrop of the corniferous limestone or of the overlying Hamilton shales, and are along the line of a broad and low anticlinal, which runs nearly east and west through the district. In the township of Derham, where small quantities of oil rise to the surface in several places, the corniferous formation is overlaid by about 40 feet of clay and sand, after sinking through which the limestone was bored to the depth of 36 feet. From this opening a few barrels of petroleum were obtained. Oil-springs abound for several miles along the Thames about 60 miles to the westward of Derham, and borings into the limestone beneath have furnished considerable quantities of oil, although not sufficient, perhaps, to be of great economic importance. The principal oil-wells of Canada occur in Enniskillen, about 20 miles to the northward of the last. Here numerous oil-springs are found, and the thickened petroleum, mixed with earthy and vegetable matters, forms layers of considerable extent at the surface of the ground and around the roots of growing forest trees. Two of these layers have together an area of more than two acres, and a thickness which varies from a few inches to 2 feet. They are locally known as gum beds. In sinking a well in the vicinity of an oil-spring in this region there was found beneath a depth of 10 feet of clay and reposing upon 4 feet of gravel a layer of bituminous matter like that just described from 2 to 4 inches in thickness. It is easily separable into thin laminae, which are so soft as to be flexible, and show upon their surfaces the remains of leaves and of insects which have become imbedded during the slow accumulation and solidification of the bitumen. This little deposit, which is mingled with a considerable proportion of earthy matter, is instructive as showing the manner in which beds of bituminous rock may sometimes be produced from previously-formed sources of petroleum.

The corniferous limestone in Enniskillen is overlaid by about 200 feet of marls and soft shales, abounding in the characteristic fossils of the Hamilton formation. To this succeed from 40 to 60 feet of Quaternary clays and sands of fresh-water origin, through which the scanty natural oil-springs rise. On sinking wells there is generally found reposing immediately upon the shales a layer of coarse gravel holding large quantities of petroleum, which is the oil of the so-called surface wells, and has accumulated beneath the clays. It is darker and thicker than that obtained directly from the rock below, on boring which fissures or seams are met with, from which petroleum issues in abundance, and often with great force, sometimes attaining the surface and often rising above it, constituting the flowing wells. These oil-bearing veins are met with at depths varying from 40 to 100 and 200 feet in the rock, and in borings near together the oil is often met with at very unequal depths. Adjacent borings sometimes appear to be connected with the same vein and to affect each other's supply. The deepest well in this region was estimated to yield, when first opened, 2,000 gallons in twenty-four hours, and, at present, where it is allowed to flow for some time, the supply in many of the neighboring shallower wells is found to fail. The facts observed in this region seem to show that these veins are fissures running obliquely downward to the great reservoir of petroleum, which is probably in the underlying corniferous limestone. The oil-wells in this township are confined to two districts, the more abundant one being about 6 miles south of the other. From the results of an unsuccessful boring made on an intermediate point, it appears that these two districts are on two slight anticlinals subordinate to the great axis already mentioned. This anticlinal structure appears to be a necessary condition of the occurrence of abundant oil-wells; the petroleum, being lighter than water, accumulates in porous strata, or in fissures in the higher part of the anticlinal, and, in obedience to a hydrostatic law, rises through openings to heights considerably above

a C. N., 6, 5, 16, 35; C. Nat. (1), 6, 245; A. J. Ph. (3), 10, 527.

b B. S. G. F., xxiv, 570.

c Since determined to be Miocene.

d Professor Kerr, state geologist of North Carolina, reported that no petroleum was known in that state.

e Since shown in Niagara limestone at Terre Haute, Indiana.

f *The Geol. Mag.*, iv, 34.

g A. J. S. (2), xxxv, 169.

h *Ibid* (2), xlv, 356.

the water level of the region. Large quantities of light carburetted hydrogen gas are found in the palaeozoic rocks of the vicinity, and seem to be in many cases accumulated in the subterranean anticlinal reservoirs, since borings sometimes yield both gas and oil, or gas alone. Water sometimes, but not always, more or less saline often accompanies the petroleum, and frequently replaces the latter in wells that have been for some time wrought. I do not conceive that the gas has any necessary connection with the oil, since large quantities of it are found in rocks which underlie the corniferous limestone. If, however, as is not improbable, portions of it were generated and now exist in a condensed state in the oil-bearing strata, its elasticity would help to raise the petroleum to the surface.

The accumulation of the petroleum along lines of uplift, and its escape through the fissures accompanying this disturbance, must evidently date from a remote geological epoch. Porous beds, like the Devonian sandstones or the Quaternary gravels, have, however, served as reservoirs in which the oil has accumulated, while argillaceous and nearly impervious strata, like the marls of the Hamilton group and the fresh-water clays which overlie the gravels in western Canada, have in a great measure prevented its escape.

Hence it would appear that the Devonian sandstones of Pennsylvania and northeastern Ohio are filled with oil which has risen from the limestone beneath, while over a great portion of western Canada this limestone was ages ago denuded, and has lost the greater part of its petroleum. (a)

There exists in southwestern Ontario, along the river Saint Clair, an area of several hundred square miles underlain by black shales in the counties of Lambton and Kent, of which only the lower part belongs to the Hamilton group. These strata are exposed in very few localities, but the lower beds are seen in Warwick, where they were many years since examined by Mr. Hall, in company with Mr. Alexander Murray, of the geological survey of Canada, and were by the former identified with the Genesee slate forming the summit of the Hamilton group. They are in this place, however, overlaid by more arenaceous beds, in which Professor Hall at the same time detected the fish remains of the Portage formation. The thickness of these black strata, as appears from a boring in the immediate vicinity, is 50 feet, beneath which are met the gray Hamilton shales. * * * * The Hamilton shale, which in some parts of New York attains a thickness of 1,000 feet, but is reduced to 200 feet in the western part of the state, consists in Ontario chiefly of soft, gray marls, called soapstone by the well-borers, but includes at its base a few feet of black beds, probably representing the Marcellus shale. It contains, moreover, in some parts beds of from 2 to 5 feet of solid gray limestone holding silicified fossils, and in one instance impregnated with petroleum, characters which, but for the nature of the organic remains and the underlying marls, would lead to the conclusion that the Lower Devonian had been reached. The thickness of the Hamilton shale varies in different parts of the region under consideration.

From the record of numerous wells in the southeastern portion it appears that the entire thickness of soft strata between the corniferous limestone below and the black shale above varies from 275 to 230 feet, while along the shore of lake Erie it is not more than 200 feet. Further north, in Bosanquet, beneath the black shale, 350 feet of soft gray shale were traversed in boring without reaching the hard rock beneath, while in the adjacent township of Warwick, in a similar boring, the underlying limestone was attained at 396 feet from the base of the black shales. It thus appears that the Hamilton shale (including the insignificant representative of the Marcellus shale at its base) augments in volume from 200 feet on lake Erie to about 400 feet near to lake Huron. Such a change in an essentially calcareous formation is in accordance with the thickening of the corniferous limestone in the same direction.

The Lower Devonian in Ontario is represented by the corniferous limestone, for the so-called Onondaga limestone has not been recognized, and the Oriskany sandstone, always thin, is in some places entirely wanting. The thickness of the corniferous in western New York is about 90 feet, and in southeastern Michigan it is said to be not more than 60 feet, although it increases in going northward, and attains 275 feet at Mackinac. In the townships of Woodhouse and Townsend, about 70 miles west from Buffalo, its thickness has been found to be 160 feet; but for a great portion of the region in Ontario underlain by this formation it is so much concealed that it is not easy to determine its thickness. In the numerous borings which have been sunk through this limestone there is met with nothing distinctive to mark the separation between it and the limestone beds which form the upper part of the Onondaga salt group or Salina formation of Dana, which consists of dolomites, alternating with beds of a pure limestone, like that of the corniferous formation. The saliferous and gypsiferous magnesium marls, which form the lower part of the Salina formation, are, however, at once recognized by the borers, and lead to important conclusions regarding this formation in Ontario. In Wayne county, New York, the Salina formation has a thickness of from 700 to 1,000 feet, which, to the westward, is believed to be reduced to less than 300 feet, where the outcrop of this formation, crossing the Niagara river, enters Ontario. * * * *

Apart from the chemical objections to the view which supposes the oil to be derived from the pyroschists above the corniferous limestone, it is to be remarked that all the oil-wells of Ontario have been sunk along denuded anticlinals, where, with the exception of the thin black band sometimes met with at the base of the Hamilton formation, these so-called bituminous shales are entirely wanting. The Hamilton formation, moreover, is never oleiferous, except in the case of the rare limestone beds already referred to, which are occasionally interstratified. Reservoirs of petroleum are met with both in the overlying Quaternary gravels and in the fissures and cavities of the Hamilton shales, but in some cases the borings are carried entirely through these strata into the corniferous limestone before getting oil. Among other instances cited in my geological report for 1866 may be mentioned a well at Oil Springs, in Enniskillen, which was sunk to a depth of 456 feet from the surface, and 70 feet in the solid limestone beneath the Hamilton shales, before meeting oil, while in adjacent wells supplies of petroleum are generally met with at varying depths in the shales.

In a well at Bothwell oil was first met with at 420 feet from the surface and 120 feet in the corniferous limestone, while a boring at Thamesville was carried 332 feet, of which the last 32 feet were in the corniferous limestone. This well yielded no oil until, at a depth of 16 feet in this rock, a fissure was encountered, from which at the time of my visit 30 barrels of petroleum had been extracted. At Chatham, in like manner, after sinking through 294 feet of shales, oil was met with at a depth of 58 feet in the underlying corniferous limestone.

We also find oil-producing wells sunk in districts where the Hamilton shale is entirely wanting, as in Maidstone, on the shore of lake Saint Clair, where, beneath 109 feet of clay, a boring was carried through 209 feet of limestone, of which the greater part consisted of the water-lime beds of the Salina formation, overlaid by a portion of the corniferous. At a distance of 6 feet in the rock a fissure was struck, yielding several barrels of petroleum. Again, at Tilsonburg, where the corniferous limestone is covered only by Quaternary clays, natural oil-springs are frequent, and by boring fissures yielding petroleum were found at various depths in the limestone down to 100 feet, at which point a flowing well was obtained, yielding an abundance of water, with some 40 gallons of oil daily.

The supplies of oil from wells in the corniferous limestone are less abundant than those in the overlying shales and even in the Quaternary gravels, for the obvious reason that both of these offer conditions favorable to the retention and accumulation of the petroleum escaping from the limestones beneath.

* * * * The conditions under which oil occurs in these limestones in Ontario are worthy of notice, inasmuch as they present grave difficulties to those who maintain that petroleum has been generated by an unexplained process of distillation going on in some

underlying hydrocarbonaceous rock. Numerous borings in search of oil on Manitoulin island have been carried down through the Utica and Lorraine shales, but petroleum has been found only in fissures at considerable depths in the underlying limestones of the Trenton group. The supplies from this region have not hitherto been abundant, yet from one of the wells just mentioned 120 barrels of petroleum were obtained. The limestone here rests on the white, unfossiliferous, chazy sandstone, beneath which are found only ancient crystalline rocks, so that it is difficult to avoid the conclusion that this limestone of the Trenton group is, like those of the Upper Silurian and Devonian age already noticed, a true oil-bearing rock. (a)

Although the discussion of the subject as presented in these two extracts proceeds in a somewhat disconnected manner, the opinions held by Dr. Hunt are plain, viz: that the oil comes from the limestones at the base of the Devonian formation, that it is indigenous in those rocks, and has accumulated under the crowns of anticlinals.

According to the latest published researches, I conclude that the geological formations in western Pennsylvania from which petroleum has been obtained belong to the Chemung and perhaps later groups of the Upper Devonian, and consist of shales and marls, interstratified with sandstones. The sandstone varies in character from a coarse-grained, uncemented sandstone to a pebble conglomerate, composed of worn pebbles of white or slightly-colored opaque quartz overlaid by marls and slates, often highly silicated, forming very hard and impervious crusts. This pebble conglomerate consists of two varieties, occupying separate horizons, in one of which the pebbles are nearly spherical, and in the other flattened. Between these beds of sandstone or conglomerate that contain the oil are beds of shale, often of great thickness, with which are thin beds of sand and "shells". The latter are thus described by Professor J. P. Lesley:

The hard "shells" or crusts of white flint found at different depths in this and many other wells, and broken with the auger-bits only with extreme difficulty, are deserving of particular investigation. They seem to form impervious sheets of precipitated silica effectual barriers against any general movement, upward or downward, of the underground drainage. (b)

The sandstones and conglomerates are of quite uniform structure over wide areas; for instance, the Venango third sand consists of smooth, rounded pebbles, while the Bradford third sand is a porous sandstone. The latter has been examined microscopically by Professor C. W. Hall, of the University of Minnesota, who, in a private communication, says:

The sandstone in the flame turned to a light gray, almost white, color through the burning out of the bituminous matter. Thin sections disclose the presence of numerous fluid cavities in some of the grains. Small as these grains are, they protected intact the fluid contents of the cavities from the penetrating effects of the petroleum which had percolated through the mass of the sandstone.

A bed of shale several hundred feet in thickness and very rich in remains of fucoids outcrops along the shores of lake Erie through Erie county, Pennsylvania, and Chautauqua county, New York, and wells drilled at Erie, Pennsylvania, to a depth of over 600 feet in this shale have yielded petroleum, but have failed to reach the underlying formation. These shales dip toward the southwest.

At Union City, in the southern part of Erie county, sandstone overlies the shale in the summits of the hills and furnishes the quarry rock for the valley of French creek. This sandstone often exhibits traces of bitumen, and when freshly quarried and exposed to the sun becomes covered with an exudation of thick oil. Farther south and east the rocks alternate between shales, sandstones, and pebble conglomerate, each of which dips south and west, and disappears under newer and higher members that succeed them on the surface. In the neighborhood of Titusville, Crawford county, the shales of Erie county have passed far below the surface, and new sandstones have appeared on the hills which border the deep and narrow valleys through which the Allegheny and its tributaries flow.

No clearer statement has been made of the relations of these rocks than that given by Mr. J. F. Carl in his reports to the geologist in charge of the second geological survey of Pennsylvania. He says:

In the first oil development by artesian wells nothing was known about the sands. Wells were drilled until indications of oil appeared, without regard to the character of the strata pierced. But experience soon proved the sand rocks to be its source, and then commenced deeper drilling for other sands, which, in the valley of Oil creek, resulted in the discovery and classification of "three sands"—these being all the oil-bearing sands found in that locality, even after several wells had been sunk much deeper in quest of others.

In the progress of development locations for wells were selected on higher ground. The drill passed now through four or five other and higher definite sand rocks before reaching the geological horizon of the first sand of Oil creek, and when this fact was made clear it became customary among drillers to throw out these upper sands from their well records. They were called the "mountain sands", and were also numbered 1, 2, 3, etc. The drillers commenced their count of the oil-rocks with that one which they found at the depth at which they supposed the first sand of Oil creek to lie; but in so doing many errors occurred, resulting from a want of accurate observation, first, as to the surface elevation of the wells drilled on high ground, and, second, as to the dip of the oil-bearing strata, which materially affected the comparison of elevations, even when these were accurately known. A third source of error may be found in the fact that a thick stratum of sand lying single and solid in one place is often split into two, or, in other words, is represented by an equivalent of two sands with shales intervening in another place, perhaps only a short distance from the first.

For several years after the discovery of oil the drilling of wells was almost exclusively confined to the "flats" bordering the principal streams. The impression prevailed that there was some connection, some parallelism, between the streams on the surface and the "oil veins" beneath; but many failures to strike oil along the streams gradually led to locations on higher ground and upon lines between good wells. This method has been pursued so long and so thoroughly that we can now affirm that the drill has traced the great oil leads of the country from point to point regardless of any and all topographical features of the surface. (c) * * *

We use the word "belt", not as employed by some to designate a narrow, continuous line of sand rock, which may be unerringly traced for miles with an instrument on a certain degree of the compass circle, but only as a convenient term for expressing the general trend of the oil-bearing rocks from point to point, even although interrupted by "dry" and unproductive intervals.

The base-line run from Pleasantville to Tidioute—from the commencement of the Colorado district to the Allegheny river—passes through what has been one of the best and most continuous oil-producing belts of the region. Along and contiguous to this line, and to the north of it, the deeply-eroded valleys of Pine creek and Dennis run expose the baset edges of the whole series of slightly-inclined rocks (uplifted toward the north) underlying the Great Conglomerate (No. XII, the base of the productive coal measures) to a (geological) depth of 850 feet, bringing us down to within about 100 feet of the third or lowest oil-bearing sands. (a)

This exposure (along Pine creek and Dennis run), taken in connection with the well records along the route, enables us to form a tolerably correct idea of the stratification of the rocks to that depth. The whole series is found to consist of bands of sandstones and conglomerates and sandy and muddy shales and slates, varying locally in character, composition, and relative order, when studied in detail, but, as a whole, lying one above another in nearly horizontal parallel planes. The local variability of stratification is particularly noticeable (at least in the southeastern part of the district) in the strata next beneath the Conglomerate No. XII, and to a relative depth of from 600 to 650 feet. These strata have never produced oil in Venango county. We may therefore call them the "barren oil-measures" of Venango, or the "mountain-sand group".

Beneath the division of mountain sands another series, with a thickness of from 350 to 400 feet, and similar to the above in structure, but rather more regular in stratification, will include the three sands of Oil creek; and, as we believe it can be shown that no oil has ever been obtained in the district except from rocks of this series, it may properly be called the "petroleum measures" of Venango, or "division of the three sands".

Some of the first wells drilled evidently obtained their oil above the first sand, and the old oil-pits of French and Oil creeks and Hosmer run were above it also. But the oil, without doubt, came really from the first sand, its close proximity to the surface in these places having admitted of the percolation of surface water into its crevices, which, by hydraulic pressure, forced the oil upward.

It is a noticeable fact that any first sand below the surface is generally full of water veins, whether it be an oil-bearing or a mountain sand. If the oil sands lie deep, they seldom (especially in new territory, before the water is let down by the drill) contain much water.

In the shallow wells at Tidioute, along the Allegheny river, and on French and some parts of Oil creek, considerable water was always pumped with the oil; but in the deep wells at Pleasantville there was not found at first one per cent. of water, and that, being salt, must have come commonly from the second sand. As the oil was exhausted the water increased. (b)

A comparison of records of wells on Oil creek, where the three leading sands of the petroleum measures lie with considerable regularity, both as to their thickness and the intervening distances between them, results in an average record about as follows:

First sand, 40 feet thick; interval, 105 feet. Second sand, 25 feet thick; interval, 110 feet. Third sand, 35 feet thick. Total, 315 feet. In addition to these three regular sands, there is found in many of the wells a fine-grained, muddy, gray sand, known among drillers as the "stray third". This lies from 15 to 20 feet above the regular third, and is from 12 to 25 feet thick. In some localities this rock assumes a pebbly character, and produces oil which is always darker than the third-sand oil, sometimes being nearly black.

At different points on Oil creek—at East Shamburg and other places—wells in close proximity to each other have produced, some of them black oil, some green, and some a mixture of both.

The "black oil" of the Pleasantville district has all been derived from the "stray third", which, in this district, is universally called the fourth, or "black-oil sand". But here the character and composition of the two sands (third and stray) are reversed. The stray is a coarse pebble or conglomerate; the third, a fine, micaceous, muddy, gray sand, only 15 to 20 feet in thickness, but always showing traces of green oil, and sometimes furnishing an abundance of gas.

We believe it can be shown also that Pithole, Cashup, and Fagundus, although producing an oil of a lighter color than Pleasantville, drew their supply from the same stray sand, and the proof will be offered farther on.

A noticeable peculiarity of these two sands (stray and third) is that on the northwestern outline of the oil-field, where the third shows itself in greatest force, the stray is seldom an oil-producing rock. As we proceed southeastward the stray begins to get its pebbly constitution and to yield oil over broader areas than the third, the latter becoming more fine and compact and gradually thinning away.

A marked difference will be noted also on comparison of specimens of the two sands. In the oil-producing stray the pebbles are of a yellowish-brown color, and in shape generally spheroidal. In the third the pebbles are white, often brilliant, and in shape lenticular. These distinguishing characteristics, we believe, hold good universally.

On the northwesterly line above mentioned the second sand lies in a massive stratum, 30 feet or more in thickness. Toward the southeast, as in a part of the Pleasantville district, at Bean farm, Pithole, Cashup, and Fagundus, it is split into two well-defined sands, with from 15 to 30 feet of slates or shales intervening. It is this that has given rise to the erroneous appellation of fourth-sand oil at Pleasantville. The drillers began to number rightly on the first; and called the split (second) sand next below it second and third, and then called the stray the fourth. This, of course, made the third sand of the Oil creek wells, which was still lower, fifth in the series.

In some localities they went still farther in their zeal to prove their territory better than Oil creek, by showing a greater number of sands. Finding the stray and third in three divisions, instead of two, they announced at once the discovery of a sixth sand.

The first sand, as far as we have examined it, appears to lie with more uniformity than the second, but further investigation may show changes of character and of level similar to the others.

Little oil has been produced from the first and second sands in the particular field under review. Their best development as oil-bearing rocks is along the Allegheny river from West Hickory to the Cochran farm, and on French creek and Two-mile run, near Franklin, to which our detailed survey of 1874 did not reach. We speak of them above as they are found on the green-oil range, and without a closer knowledge of the peculiar structural differences which they may be found to exhibit in the places above named on the Allegheny river and French creek.

Assuming, then, that all the oil from this country has been deduced from the "group of the three oil sands", consisting of the first, second, stray, and third, with their intervening slates, shales, and mud rocks, and that the trend of the oil-producing belt is marked by no surface indications to point out its direction or drift, we will proceed, on the principle of a general parallelism of strata, to trace the sands by means of the levels run, combined with the records of wells, through some of the main oil centers of the district, with a view of ascertaining the direction of the dip of the series and the fall, in feet, per mile.

The Venango petroleum district, or "upper oil belt", as it is now generally called, in contradistinction to the Butler county district, may be said to commence a short distance east of Tidioute. From thence southwestward it is marked by an almost unbroken band of wells through Dennis run, Triumph, the Clapp farms, New London, the Ware farm, and Colorado, a distance of about 9 miles.

Between this, its southwest end, and the commencement of the Shamburg district, near the National wells, no paying third-sand wells are found, except, perhaps, within a limited area on the Benedict farm, west of Enterprise, the exact geological relations of which to the Colorado "lead" has not been fully determined.

Beneath this unproductive district the third sand is found in all the wells drilled, having a thickness of from 30 to 45 feet, but apparently too fine-grained and closely compacted with mud to produce oil.

Between Shamburg and Petroleum Centre, on Oil creek, occurs another unproductive interval; but from Petroleum Centre the oil-belt has been traced with considerable continuity, crossing the Allegheny river at Reno, again at Foster's, and terminating at Scrubgrass.

This line of development, it will be noted, leaves Tidioute in a direction of about south 80° west, gradually sweeping around toward the south, and ending with a bearing of only about south 20° west.

The belt above described, it should be understood, is the green-oil or third-sand belt. It appears to be much narrower and more sharply defined than others. At many places a distance from the center line toward the north or toward the south of merely a few rods suffices to guarantee a "dry hole".

From levels taken along the surface line above described, combined with such records of wells as were obtained, the elevation of the top of the third sand in the several localities named is ascertained to be as follows:

	Feet above tide.
At Tidioute.....	995
At Colorado.....	840
At Pleasantville.....	755
At Shamburg.....	710
At Petroleum Centre.....	640
At Rouseville.....	545

Distance from Rouseville to Tidioute, 20.7 miles; difference in elevations, 450 feet; dip per mile, 21.7 feet. (a)

In the report made subsequently, and published in 1880, Mr. Carll continues the discussion of this subject. Want of space forbids my quoting more liberally from this report, but the following extracts present the relation and stratigraphy of these formations:

The designations first, second, and third mountain sands, used provisionally in 1874, answered very well for the purposes of that local report; but to adhere to the use of these ordinal numbers still, after the comparison of oil-well and surface sections has been extended southwestward to the very borders of the state of Ohio and northeastward into the southern counties of the state of New York, would only perpetuate confusion in our geological nomenclature.

The first mountain sand appears to occupy the horizon of the Connoquenessing sandstone of Butler county and the Kenzua creek sandstone of McKean county, and may as well be spoken of when occasion requires under one of those two names.

In the *Reports of the Pennsylvania Survey*, vol. III, page 83, appears the following in relation to this subject:

The second mountain sand cannot, indeed, be robbed entirely of its name; but whenever it is thus spoken of the name must be accounted as a mere synonym for the Garland conglomerate, and not at all as an index to the numerical position of the rock in relation to other sands in the series. But it will always be the Garland-Olean-Sharon-Ohio conglomerate.

The third mountain sand will receive in this report a new name, the Pithole grit. This rock was first recognized as a persistent sandstone in the Pithole oil-wells, being well developed in all that country, and making conspicuous outcrops along the Allegheny river on the south, and along Oil creek on the west. The term *grit* sufficiently designates it as a sandstone; but, what is more important, will serve to associate it in the reader's mind with the Berea grit of Ohio, which seems to have been a contemporaneous formation, although the two rocks have not been traced across the country toward each other to a common place of actual meeting.

Neglecting for the present the mountain sands as separate numbers of a small series, and grouping them and their intervals together as a whole, I must now show that they constitute one (and the upper) member of a larger series. The vertical section of rocks in the oil belt, as exhibited by the well records, show these characteristic subdivisions:

1. Mountain sands, so called by the oil-well drillers.
2. Crawford shales, a group of shales and mud rocks, in the midst of which is the Pithole grit.
3. Venango oil-sands, a group of sandstones and shales interleaved.

These names will be useful in defining those features of hardness and softness by which the driller classifies the rocks through which his well passes downward; but they must not be taken by the geologist to signify formations of these successive and distinct ages, plainly and absolutely separated from each other; for such dividing planes cannot be satisfactorily established from the imperfect records of oil-wells alone.

It is important to state the fact clearly at the outset that throughout the whole area which has afforded the Venango oil—that is, along the entire length of the oil-producing belt (or belts) of country—the structure of the oil-sand group is virtually the same. On the other hand, the moment we leave the oil-producing area to the right or to the left the internal constitution of the oil-sand group becomes quite different. All the wells that pierce the oil-producing belts exhibit remarkably the same group of oil sands. All wells put down outside of these belts exhibit quite a different kind of deposits when they reach the plane of the oil sands. (b)

From data too voluminous to quote here, Mr. Carll concludes that "the Venango oil sands as a group not only thin away, but disappear, and are wanting in the Slippery Rock country". Farther to the southwest, in Beaver county, he concludes that "not only is the oil group cut out, and also the red rock over it, but the sandstone deposit occupying the horizon of the Pithole grit is enlarged; the shaly interval above the sandstone becomes sandy; and thus the true base of the mountain-sand series becomes somewhat obscure". He further concludes:

It follows from this study of our sections that the Ohioville (Smith's ferry) amber oil must be derived from the horizon of the Pithole grit, which also furnishes *amber oil* in small quantities on Slippery Rock creek. It follows as logically, also, that the Slippery Rock heavy oil is found in one of the lower members of the mountain-sand series, an horizon which also produces heavy oil in many wells at Smith's ferry. (c)

Continuing the discussion, Mr. Carll states:

No direct connection has yet been discovered between the upper or Tidioute-Bullion oil belt and the lower or Clarion-Butler oil belt. The present southern termination of the line of productive wells on the upper belt is near Clintonville, in Venango county. This is about 12 miles northwest of Columbia hill, in Butler county, which is the nearest point of development in the lower belt. The lower belt

a *Report Second Geological Survey Pennsylvania*, I, 1874, p. 18.

b *Ibid.*, III, p. 83.

c *Reports*, III, p. 90.

is known to extend south-southwesterly from Columbia hill into Summit township, Butler county, some 20 miles, and northeasterly into Elk township, Clarion county, some 15 miles. The area of country between the belts has been tested in hundreds of places with result in most cases quite unsatisfactory. Nevertheless several good pools of oil have been discovered. These, however, do not establish connection between the belts, for the stratification is somewhat irregular throughout all this district as far as is known, and the continuity of the oil-producing rocks seems to be here interrupted. We cannot, therefore, speak of the upper belt as being directly connected by line of paying wells with the lower; yet the main structural features of the group in the upper belt are observable across the interval and the rocks themselves reappear with their characteristic aspect as soon as the lower belt is reached.

That the deposits of the lower belt have been subjected to more vicissitudes of water level than those of the upper belt, resulting in a greater number of alternating bands of sandstone and shale within the vertical limits of the group, seems evident; yet it cannot be doubted that the deposit in the two belts were being laid down at one and the same time. They occupy the same geological horizon they are associated with similar strata; and they exhibit a like parallelism of structure. Geologically, therefore, the two belts may be viewed as one, and may be studied and described accordingly. (a)

Concerning the geological age of the oil-sand group, Mr. Carll remarks:

Previous to our present survey the Venango oil-sands were universally regarded as of Chemung age. In the summer of 1875 evidence began to accumulate pointing strongly toward the probability that they were of more recent date; but the idea seemed then so heterodox and the facts to support it were at first so meager and questionable, that no definite conclusion on the subject could be immediately arrived at. Even now their relative place in the paleozoic column of eastern Pennsylvania cannot be precisely and positively indicated. We can only say there are reasonable grounds for inferring that they do not belong to the Chemung formation, as represented in New York state and eastern Pennsylvania. (b)

A comparison of the structure and depth of sediment belonging to the Catskill, the Pocono, and the Mauch Chunk periods in eastern Pennsylvania with those of the same ages in western Pennsylvania leaves little room to doubt that the former represent deposits in a much broader and deeper sea than the latter: a sea perhaps whose bottom was undergoing a steady depression in the east while it was alternating between depression and elevation and gradually shallowing in the west. An elevation of the ocean bottom near the close of the Chemung period seems to me to have thrown off the waters from a large portion of its former bed in the west, leaving submerged in that direction only a narrow arm of the sea, representing perhaps some old submarine valley. This comparatively contracted and shallow basin must necessarily, from the very nature of the case, have been the repository of immense deposits of reworked Chemung sediments, rapidly brought into it from the newly emerged mud-land, to be interbedded with the Catskill reds, which were intermittently swept in from the east to greater or less distances as circumstances directed. We might then expect to find in this basin precisely what the drill discloses: alternations of Catskill red and Chemung gray argillaceous shales occupying the deepest part of it, and more sandy deposits lying around its edges. (c)

Concerning the structure of the oil-sand group, Mr. Carll insists that the integrity of the Venango oil-sand group must be kept in clear view, as it is a group in the strictest sense of the term, and has a well-defined top and bottom. (d) The sandy layers at the top of the Crawford shale are of no moment in the present discussion. The sole fact here insisted on is this:

1. That over the oil-sand group lies a distinct soft formation, 300 or 400 feet thick, in all parts of the oil regions of western Pennsylvania, which, for the present, we call the Crawford shale, in the middle of which appears, in some parts of the region, a massive sand deposit, called in this report the Pithole grit.

2. That the well-sinker will find an abrupt change of character when he gets through this soft formation and strikes the top of the oil-sand group. The transition from the soft Crawford shales or slates to the first oil sand is sharply defined, and the geologist is obliged to see here the close of one period of deposits of one kind and the beginning of another period of deposits of a very different kind. (e)

Mr. Carll continues:

Under the oil-sand group again lies a perfectly well-marked different formation. The driller having gone through the Venango oil sands and their separating shales and reached the base of the group, suddenly, by as abrupt a transition as that he encountered at its top, enters a different set of rocks. Wherever the group is normally developed the drill passes at once from sandstone into shale, and continues from that point in the well to go steadily down through shales for hundreds of feet without encountering any sandstone layers like those above.

A large majority of oil-wells were never drilled below the third sand or base of the group, for experience had convinced operators that it was useless to expect another sand layer below that horizon along the whole line of the Venango and Butler belts. Several hundred wells, however, were put down to depths of from 100 to 500 feet beneath the lowest Venango oil sand. Their numbers, and the extent of ground over which they lie scattered, afford conclusive evidence that the measures beneath the oil-sand group have everywhere the same clay characters. The universal testimony of their records is, soft drilling and no coarse, massive sand rock after leaving the productive oil measures. Occasionally, indeed, a "sand" has been reported, and some fine-grained sandstone layers were to be expected, for they are not unknown in the Chemung series; but it is now conceded that such layers do not resemble the oil sands, and that they occurred so rarely, and the reports of them are so vague and questionable, that we are warranted in treating them as mere local variations of some of the beds of the Chemung shales. (f)

The Venango oil-sand group itself is a mass of sandstone deposits from 300 to 380 feet thick, with layers of pebbles and many local partings of shale and slate. These figures may be varied somewhat, but it will be found as a general rule that a thickness of 350 feet will, in nearly every case, embrace all the sands belonging to the Venango group, even the fourth, fifth, and sixth sands, as the lower members of the group in some localities have been called. It is wonderful how the group maintains its total thickness with such uniformity for a distance of 62 miles in a straight line from Tidoute, in Warren county, to Herman station, in Butler county. The top sand is sometimes 10 feet thick, and sometimes 85 feet; the bottom sand may be 5 feet thick, or it may be 120 feet; and so either one of these members may individually vary in thickness about as much as the whole group is found to vary. (g)

a Reports, III, p. 100.

b *Ibid.*, p. 119, § 297.

c *Ibid.*, p. 122, § 302.

d *Ibid.*, p. 128, § 315.

e *Ibid.*, p. 130, § 318.

f *Ibid.*, p. 132, § 320.

g *Ibid.*, p. 136, § 323.

The following table, compiled from those prepared by Mr. Carl, shows the elevation above tide-level, the fall, distance, and rate of fall per mile of the top of the third oil-sand in Warren, Venango, Clarion, and Butler counties. Dogtown is at the same level above tide-water as Clintonville, one mile northeast of Turkey City (see map III):

Above tide.		Course.	Fall.	Miles.	Rate.
Feet.			Feet.		Feet.
1,008	Along axis of Venango belt:				
230	Tidioute to—				
	Clintonville along line of development.....		778	42.23	18.42
	Ditto, bee-line.....	S. 39° W.		39.50	19.70
230	Along axis of Butler-Clarion belt:				
—418	Dogtown to—				
	Herman station along line of development.....		648	29.83	21.72
	Ditto, bee-line.....	S. 27° W.		28.25	22.04
370	Shippensburg to—				
—418	Herman station—				
1,008	Tidioute to.....		788	37.49	21.02
—418	Herman station (*).....	S. 21° W.	1,426	62.00	23.00

* Reports, III, p. 144.

These figures show that the top of the third Venango oil-sand dips to the southwest in the 62 miles between Tidioute, in Warren county, and Herman station, in Butler county, at the average rate of 23 feet to the mile.

The first paying oil-well on the Butler-Clarion belt was obtained on the Allegheny river at Parker's landing in the fall of 1868, and operations spread out but a short distance from that point during the years 1869 and 1870.

In 1871 the somewhat unexpected measure of success attending the test wells, which were advancing toward the northeast into Clarion county, and also those toward the southwest into Butler county, led to developments in both these directions which resulted in pretty thoroughly outlining within the next three years the main or central belt.

Subsequently side lines of development were run, and the district was found to widen out in many places and to contain side belts and pools, with oil sometimes in the fourth sand, sometimes in the third, and in some localities even in rocks above the third sand, all of which aided very materially in augmenting the production. * * *

In 1874 the maximum development of this district was reached during the great fourth sand or "cross-belt" excitement. (a)

At Parker's landing the oil came from the lowest member of the oil group, the representative of the Oil creek third sand, and so the rock was very properly called, not the fourth sand, but the third. In Clarion county, however, and likewise in Butler, the oil first obtained came from a rock higher in the series. But the drillers of the early wells did not notice the change from one horizon to another, and consequently supposed that they were still getting the oil from the Parker third sand. After the development had reached Modoc and Petrolia, it began to be suspected that there might be two oil horizons, instead of only one, and then commenced the experiment of deeper drilling at Petrolia and elsewhere, which finally resulted in the development of the "cross-belt", which was also called the "fourth-sand belt". (b) * * *

When Bradford first began to give signs of promise as an oil-field, the map of western Pennsylvania being consulted, the embryo development was found to be on a nearly direct continuation of the Clarion county oil belt. Immediately several transit lines were started by different parties and run through from the old to the new ground. Each surveyor had his own particular angle of deviation from the meridian to run by; and each one, as far as possible, carefully kept the exact bearing and location of his line a secret.

A statement was published at that time and much quoted as a proof of the unerring exactness of this method of tracing an oil belt, provided the bearing of the "lead" had been properly calculated. As the story went, a "belt-line expert" ran one of these lines 65 miles through an almost unbroken forest, employing an engineer who had never been over the country before, and who knew absolutely nothing about the work beyond the bald fact that he was traveling by a designated degree of the compass. Nevertheless the line thus run conducted its fortunate projector out of the woods, down the mountain side, into the valley of Tunawant creek, to a station within a few feet of the largest well at that time known in the Bradford district. And this termination of the line was considered by many as a conclusive proof that all the lands through which that line passed were "on the oil belt".

The profile section (Plate VII) and the vertical section (Plate VIII) have been prepared for the purpose of exhibiting the fallacy of such views, and to enable the reader to see at a glance what some of the fundamental features of the sedimentary structure of the oil region especially are.

The profile section (Plate VII) follows a line upon the map drawn from Black Rock, on the Niagara river, in Erie county, New York, to Pittsburgh, and thence to Dunkard creek oil-field, in Dunkard township, Greene county, Pennsylvania, close to the West Virginia state line. From Black Rock to Pittsburgh the bearing of this line is S. 20° W.—distance about 175 miles. From Pittsburgh to Dunkard creek its bearing is S. 3° E.—distance 50 miles.

Starting at Black Rock, the line crosses the foot of lake Erie and strikes the southeasterly shore at Lakeview, in Erie county, New York. Thence it runs through, or very near to, the following places: Jamestown, New York; Youngsville, on Broken Straw creek, in Warren county, Pennsylvania; Tidioute, on the Allegheny river, in Warren county; President, on the Allegheny river, in Venango county; Foxburg, on the Allegheny, in Clarion county; Parker's Landing, on the Allegheny, in Armstrong county; and Petrolia, Millerstown, and Great Belt City (or Summit), in Butler county. Thus it may be said to follow the Butler oil belt very nearly along its line of best development.

It is evident that, as this alignment of the profile section coincides geographically so nearly with the trend of the Butler and Venango oil-sands, there can be no trouble in properly locating upon it the Venango oil-sand group.

The Warren oil development, however, lies some 8 miles to the east-southeast of our line, and the Bradford oil development some 30 miles from it, in the same direction.

Now, it is a remarkable and important fact that in no boring in Pennsylvania has the Warren group of oil-rocks (unmistakably developed) been seen directly beneath the Venango group. It is equally a fact that in no boring has the Bradford "third" sand been seen directly below the Warren group. In other words, we have not a single direct oil-well measurement between these several groups, and therefore we must trust to some pretty nice and difficult calculations when we try to determine the thickness of these intervals; that is, when we attempt to place the Warren and the Bradford oil-rocks in their proper places in our profile section. But whatever inaccuracies of detail may thus creep into the section, it will still suffice to show the relative positions of such oil horizons as have been profitably worked in different parts of the country. It will certainly demonstrate the folly of drilling on so-called belt lines, run from one producing district to another, regardless of the age or equivalence of the rocks to be connected.

The lowest horizon in our country from which oil in paying quantities has been obtained is that of the corniferous limestone formation, the home of the Canadian oil.

This rock can be unmistakably identified at Black Rock, in New York; and therefore Black Rock has been selected as the northern end of our profile section (Plate VII). The next and only other point at which the elevation of the corniferous limestone can be fixed is in the Coburn gas-well, at Fredonia, Chautauqua county, New York, for in our own state, as far as is known, it has never been reached by the deepest borings.

The average pitch of the corniferous limestone toward the southwest can be calculated from its elevation at Black Rock and at Fredonia, allowing us to judge approximately of the thickness of the measures between it and the Venango oil group. At Black Rock, as shown by the quotations below, the exact thickness of the rock is not known. We have assumed the top to lie about 52 feet above the surface of lake Erie, or 625 feet above ocean level, which cannot be far wrong. In the Coburn well at Fredonia it is said to have been struck at a depth of 1,050 feet, which (the elevation of the well mouth being 735 feet) puts it 315 feet below ocean level at that place. The distance from Black Rock to Fredonia is about 38 miles in a direction S. 35° W., and this gives an average slope or dip of about 25 feet per mile. But along our section line (S. 20° W.) the average dip of the limestone ought to be stronger than 25 feet per mile, because the line runs more nearly in the direction of the line of greatest dip, as calculated from other strata which admit of more accurate tracing; and this inference is strengthened by the fact that no limestone is reported in Jonathan Watson's deep well near Titusville.

The distance from Black Rock to Watson's well is about 100 miles; direction, S. 26° W.; elevation of well mouth, 1,290 feet above ocean; depth of well, 3,553 feet. On an average slope of 25 feet per mile the limestone should have been found at 1,875 feet below ocean level, or 3,165 feet from the surface; but as no limestone was seen in the well, we must conclude either that it is absent in that locality (which is hardly probable), or that it has a greater average dip slope than 25 feet per mile in that direction. As the well stopped at 2,263 feet below ocean level, an average of 29 feet per mile would put the limestone at 2,275 feet, or 12 feet beneath the well. A hard rock was reported, however, just as the utmost limit of drilling cable forced a suspension of the work at a depth of 3,553 feet from the surface. A number of other deep wells are shown on the profile, but it will be seen that none of them have gone deep enough to reach the corniferous limestone. The Watson well is not only the deepest boring ever made in western Pennsylvania, but it is also deeper geologically than any other. It is greatly to be regretted, therefore, that so little can be known of its history.

A person unacquainted with the laws of sedimentary deposition and with the methods of preparing a profile section might inadvertently be led to suppose, from an examination of the profile section (Plate VII), that the different strata represented there spread out continuously and universally in every direction under the oil regions; that a well failing to produce oil in the Venango group might be put down 400 or 500 feet deeper and pump oil from the Warren group, and then 500 feet deeper and renew itself in the Bradford "third" sand; but such has not been the experience of oil producers. The several groups of oil-producing rocks are locally well defined under certain areas; but they have their geographical as well as their geological limits, and as far as at present known the geographical limit of one group never overlaps that of another. If we take a map and outline upon it the limits of the Smith's Ferry and Slippery Rock oil-producing district, and then the Butler, Clarion, and Venango, and then the Warren, and then the Bradford, we shall see that each has its own particular locus, and that the different districts are separated from one another by areas (of greater or less extent) which have been pretty thoroughly tested by the drill and proven to be unproductive. It must have been true in all ages that every deposit of sandstone in one locality must have been represented by contemporaneous deposits of shales in other localities. Hence it happens that in tracing rocks long distances the sandstones disappear and shales come in at the same geological horizon. It may not then be presumed that each particular sandstone, or its oil, will be found in every locality where its horizon can be pierced by the drill, or that a measured section of the rocks in one place can be precisely duplicated in detail in another. The vertical section (Plate VIII) is intended to show that oil has been produced from ten or twelve different geological horizons in the earth's crust, ranging through a thickness of about 4,500 feet of sedimentary strata; and the most skillful oil producer, the most expert geologist, cannot tell how many other oil horizons may exist at intermediate depths beneath the surface (*i. e.*, in the scale of the formations), but which, being good only within certain geographical limits, have as yet escaped the oil-miner's drill (see Plate V).

VERTICAL SECTION.

SUMMARY SKETCH OF THE FORMATIONS EXHIBITED IN THE VERTICAL SECTION (Plate VIII).—This generalized section extends from the surface rocks in the upper barren coal series of Greene county, Pennsylvania, down to the corniferous limestone, the Canadian oil-rock, and will enable any one to distinguish and locate the several oil horizons thus far discovered and profitably worked in these measures. It is in fact an enlarged representation of the features presented in the profile section. (Plate VII.)

GROUP No. 1.

UPPER BARREN COAL MEASURES B.—"Greene county group;" thickness, 600 feet.

VERTICAL RANGE.—From surface to top of Washington upper limestone.

COMPOSITION.—Shales, sandstones, thin beds of limestone, and coal.

EXPOSURES.—The highlands of central and southwestern Greene county, Pennsylvania.

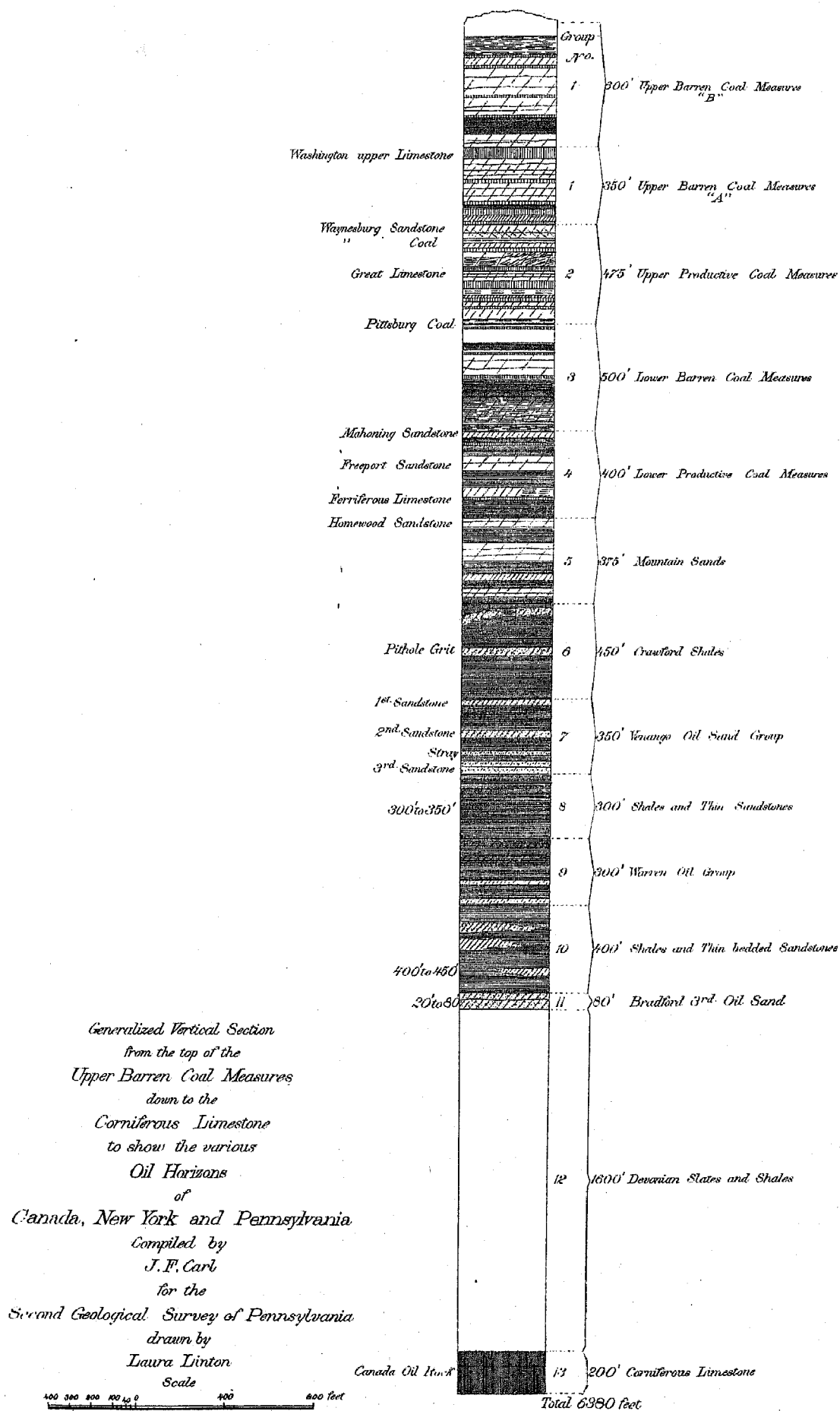
AUTHORITY.—Professors J. J. Stevenson, Report K, p. 35, and White and Fontaine, Report PP, Pennsylvania Survey.

UPPER BARREN COAL MEASURES A.—"Washington county group;" thickness, 350 feet.

VERTICAL RANGE.—From top of Washington upper limestone to top of Waynesburg sandstone.

COMPOSITION.—Shales, sandstones, limestones, and thin beds of coal; but carrying also the "Washington coal-bed", from 7 to 10 feet thick. In Washington county six beds of limestone compose about one-third of the mass, but in Greene the limestones are thin and less frequent.

EXPOSURES.—In the highlands of Washington and Greene counties (see Report K, p. 44, Pennsylvania Survey).



GROUP No. 2.

UPPER PRODUCTIVE COAL MEASURES.—Thickness, 475 feet.

VERTICAL RANGE.—From top of Waynesburg sandstone to base of Pittsburgh coal.

COMPOSITION.—Shales and sandstones, with three thick bands of limestone and several thick coal-beds, of which the Waynesburg and the Pittsburgh are the most important.

EXPOSURES.—Throughout Washington, Greene, and Allegheny counties (see detailed section in Professor Stevenson's Report K, p. 57).

GROUP No. 3.

LOWER BARREN COAL MEASURES.—Thickness, 500 feet.

VERTICAL RANGE.—From base of Pittsburgh coal to top of Mahoning sandstone.

COMPOSITION.—Shales and sandstones, with some thin beds of limestone and coal.

EXPOSURES.—Partially seen in Washington and Allegheny counties and in the highlands of southern Butler, but better developed in Beaver county, where Mr. White's detailed section of these measures was taken (see Report K, pp. 75, 76).

GROUP No. 4.

LOWER PRODUCTIVE COAL MEASURES.—Thickness, 400 feet.

VERTICAL RANGE.—From top of Mahoning sandstone to top of conglomerate No. XII.

COMPOSITION.—Sandstones and shales, with several good and persistent coal seams and two important beds of limestone—the "Freeport" and the "Ferriferous".

EXPOSURES.—This series is exposed over a large extent of country in Butler, Armstrong, Clarion, Beaver, Lawrence, and Venango counties (see Mr. Chance's detailed section, Report V, p. 16).

Professor Stevenson states (Report K, p. 392) that the Mahoning sandstone, the top member of this group, is the central and principal oil-bearing rock of the three sands found in oil-wells on Dunkard creek, Greene county. It also appears to be an oil-producing rock in Westmoreland county, where a number of oil- and salt-wells have been sunk through it.

The Ferriferous limestone of this group is the great limestone of Butler, Armstrong, and Clarion counties, and the oil-miner's "key-rock" in sinking oil-wells in these sections. It is from 5 to 25 feet in thickness, and lies from 30 to 80 feet above the Homewood sandstone, the top member of conglomerate No. XII.

GROUP No. 5.

MOUNTAIN SAND SERIES, including the Pottsville conglomerate No. XII, and probably in some localities some of the sandstones belonging to the Upper Pocono sandstone No. X (No. XI being either thin or wanting); thickness from 350 to 425 feet, say 375 feet.

VERTICAL RANGE.—From top of Homewood sandstone to the base of the Olean-Garland-Ohio conglomerate, or second-mountain sand of the Venango oil-wells.

COMPOSITION.—A group of variable conglomerates and sandstones interstratified with shales and inclosing sporadic beds of iron-ore and coal, two of the coal-beds, the Mercer and Sharon, being of great importance. It also carries in some localities two thin bands of limestone (the Mercer Upper and Lower).

EXPOSURES.—In the highlands of Mercer, southern Crawford, Venango, Forest, Warren, and McKean counties. The lower members of this group produce heavy oil at Smith's Ferry, in Beaver county, and on Slippery Rock creek, in Lawrence county, and the upper conglomerate is said to be the source of some oil in Kentucky (also in Johnson county, Kentucky).

GROUP No. 6.

CRAWFORD SHALES.—Thickness, from 400 to 500 feet, say 450 feet.

VERTICAL RANGE.—From the base of the mountain-sand series to the top of the Venango oil group.

COMPOSITION.—Shales and slates, inclosing the Pithole grit, near the center of the mass. In some localities 100 feet or more of the lower part is composed of red shale; in others no red appears. The upper part in some sections contains quite important beds of sandstone.

EXPOSURES.—Only favorably seen in cliffs bordering the streams in parts of Forest, Venango, Mercer, Crawford, Warren, and McKean counties, its northern outcrop being always obscured by drift.

The horizon of the Pithole grit appears to furnish the light-gravity amber oil at Smith's Ferry and Ohioville, in Beaver county, with traces of the same on Slippery Rock creek, in Lawrence county. It also probably yields the heavy lubricating oil of the Mecca district, in Trumbull county, Ohio.

GROUP No. 7.

VENANGO OIL GROUP.—Thickness, from 300 to 375 feet, say 350 feet.

VERTICAL RANGE.—From the top of the first oil-sand (the "second sand" of the driller in Butler county) to the bottom of the third oil-sand (called the "fourth sand" in Butler, Armstrong, and Clarion, and the "fifth sand" in some parts of Venango county).

COMPOSITION.—A group of variable sandstones, in some places conglomeritic, and locally divided into several members by irregular beds of slates and shales, some of which are red.

EXPOSURES.—These rocks, as a group, lie with a remarkable uniformity of slope and general structure in a comparatively narrow belt, from Herman station, in Butler county, to Tidioute, in Warren county. They make no conspicuous outcrops to the northwest, but appear to lose their sandy characteristics before reaching the surface.

At Tidioute the deep gorges of Dennis run and the Allegheny river expose the *first and second oil-sands*, and as far up as Warren it is quite probable that we see the upper portion of the group exposed in the river hills. These are the only localities where a portion of the group in even an approximately normal condition may be seen above water-level. Its horizon is cut through by many of the ravines of McKean county, but it has there become so changed in its physical aspects that it disappears or becomes unrecognizable when the proper range for its outcrop is reached. These are the oil-sands of Tidioute and Colorado, Warren county; Fagundus, Forest county; Church run and Titusville, Crawford county; and of all the well-known oil centers in Venango, Clarion, Armstrong, and Butler counties. They produce oil in different localities from the members of the group, ranging from 30° to 52° in gravity, and varying greatly in color:

green oil from the third sand on Oil creek; black oil from the stray sand at Pleasantville; amber oil from the second sand in many places; and dark, heavy gravity oil from the first sand at Franklin. There are also occasional local deposits of oil, shading from a light straw color to almost a jet black.

GROUP No. 8.

INTERVAL BETWEEN THE VENANGO AND THE WARREN OIL GROUP.—Thickness, 300+ feet.

VERTICAL RANGE.—From the base of the Venango third oil-sand to the top of the Warren oil group.

COMPOSITION.—Soft shale of a bluish-gray color, but containing some beds of green, purple, and red, with irregular bands of thin-bedded bluish-gray sandstones.

The wells at Warren, even when favorably located, do not pass through the Venango group in its normal condition, nor do the wells on the Venango belt, when sunk to the proper depth, as many of them have been, find the Warren oil shales and sands with oil; consequently no direct measurement of this interval can be made in oil-wells. In the section we have assigned a thickness to the mass which places the Venango and Warren oil groups as near as may be in their proper relative positions vertically at Warren.

GROUP No. 9.

WARREN OIL GROUP.—Thickness, about 300 feet.

VERTICAL RANGE AND COMPOSITION.—This group may be viewed as including the so-called second, third, and fourth sands of Warren; but its composition is so variable in different parts of the district that it does not afford any persistent bands of sandstone by which to define either its upper or its lower limit. At North Warren the upper part is shaly, and the largest wells, it is claimed, flowed from these shales, while others got their oil from the "third sand". At Warren the "second sand" is fairly developed, but the oil generally comes in the "third sand". At Stoneham a lower sand, the "fourth", produces the oil. Thus the North Warren shales are represented at Stoneham by more sandy measures which contain no oil, and the Stoneham "fourth sand" is poorly developed at North Warren, and is unproductive. The group, then, may be said to extend from the top of the North Warren shales to the bottom of the Stoneham sandstone, covering an interval, as nearly as may be calculated, of about 300 feet.

GROUP No. 10.

INTERVAL BETWEEN THE WARREN OIL GROUP AND THE BRADFORD "THIRD SAND".—Thickness, from 400 to 450 feet, say 400 feet.

VERTICAL RANGE.—From the Stoneham oil-sand to the Bradford oil-sand ("third").

COMPOSITION.—Slates and shales, generally of a bluish color, but sometimes inclined to red or brown, interstratified with thin bands of bluish-gray micaceous flaggy sandstones. The sand pumpings show this interval to be very fossiliferous.

Similar difficulties are encountered in estimating the thickness of this group to those mentioned in No. 8. A large number of wells have been sunk between Bradford and Warren, but the rocks are so variable in composition and the well records have been so imperfectly kept that no completely satisfactory identification of the rocks of the Warren oil group, with their equivalents at Bradford, or of the Bradford "third sand", with its corresponding stratum at Warren, can yet be made. The interval between the two oil horizons, however, appears to be in the neighborhood of 400 feet, as above given. This interval holds the Bradford "second sand", which has yielded oil in many of the McKean county wells, and also the sandy shale horizon producing "slush oil" along the Tuna valley.

GROUP No. 11.

BRADFORD THIRD SAND.—Thickness, from 20 to 80 feet.

COMPOSITION.—A fine-grained, light to dark brown sandstone, containing pebbles the size of pin-heads in some localities, while in others it is little more than a sandy shale. It appears to be rather thin and irregularly bedded, is frequently interstratified with thin layers of gray, slaty sandstone, and contains many fossil shells and fish bones. The constitutional peculiarities of the rock, its color, its composition, and its structure, insure its ready recognition by the driller in any locality where he may find it in even an approximately normal condition. But this rock, like all others, has its geographical limits, outside of which its geological horizon can only be traced by the exercise of the greatest of care and the best of judgment in keeping and studying the well records.

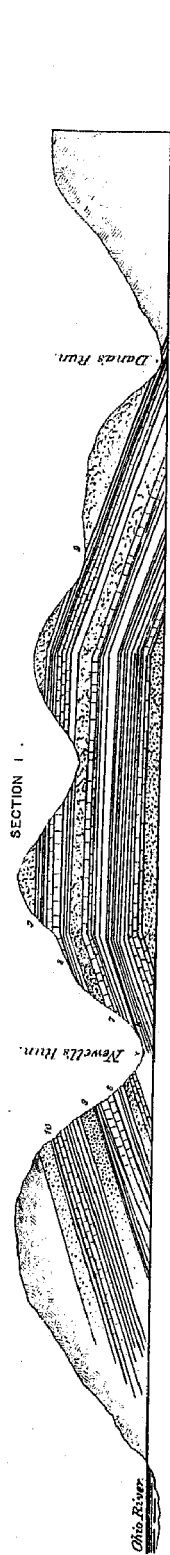
It is seldom, however, that good records of wells on debatable territory are kept. The well-owner always starts the drill on the presumption that the oil-rock will be found. He calculates in his own way its approximate depth from the surface, and makes a contract to drill so many feet. Confident of success, he urges on the drill, making no particular note of the character of the upper rocks; but when the supposed horizon of the sand is reached, and the evidences of its presence do not appear as anticipated, he discovers, too late, that he has nothing to check by to ascertain whether the oil-rock is actually wanting or only so changed in character as to be scarcely recognizable, or whether there may not have been some mistake in calculating its position in the well. Thus it often happens that wells of this class are abandoned after drilling in doubt for a few days without having been sunk to the proper depth, while others are carried on down many feet below the horizon of the sand they are in quest of, and much valuable information is lost which a little prudent foresight might have secured.

The Bradford "third sand" may be satisfactorily located in the Wilcox wells, near the southerly line of McKean county. At Tidioute, in Warren county, 35 miles nearly due west from these wells, the base of the Venango group is well defined. Between these two points, the nearest geographical approximation that can at present be made, both groups evidently undergo rapid and radical changes in composition, and the well records are vague and unreliable; hence no absolute determination of the thickness of the mass of shales lying between the two groups can here be made.

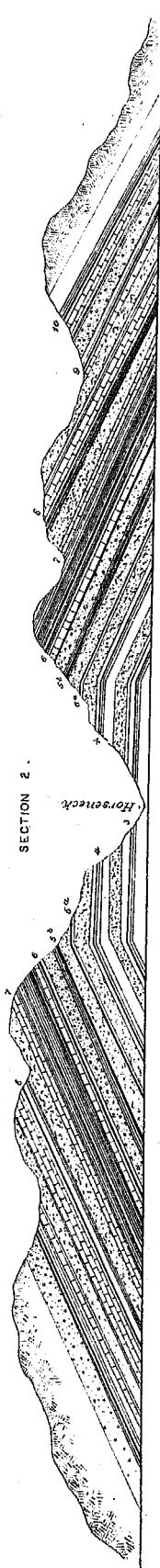
Somewhat better facilities are afforded for a study of these measures by carefully tracing the rocks from Tidioute to Warren (15 miles), and then from Warren to Bradford (25 miles); but even along these lines the structure is so obscure that mistaken identifications are quite likely to be made.

These facts are stated to explain why there is yet some uncertainty regarding the thickness of the vertical interval between the Venango oil group and Bradford "third sand". The figures cannot differ materially, however, from those given in the vertical section, Plate VIII.

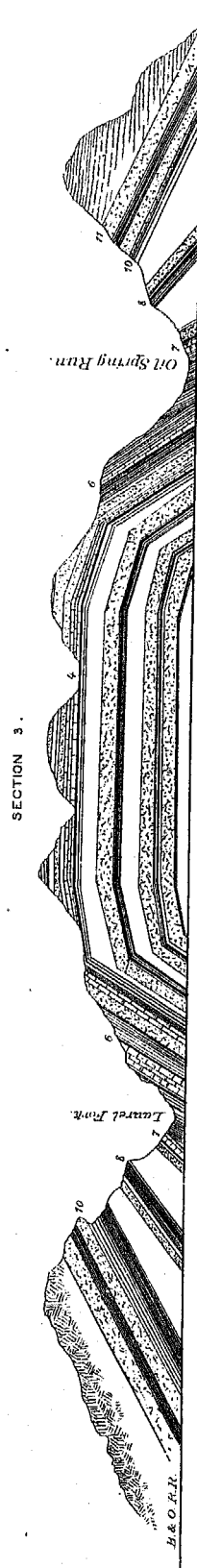
Plate IV.



SECTION ON THE OHIO RIVER ABOVE MARIETTA.



SECTION AT HORSE-NECK, WEST VIRGINIA.

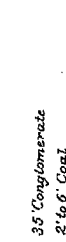
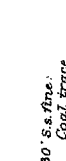
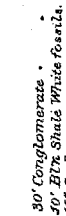
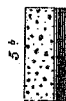
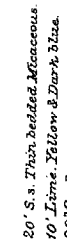
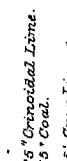
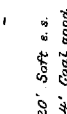
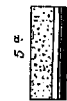


SECTION BETWEEN LAUREL FORK JUNCTION AND PETROLEUM,
WEST VIRGINIA.

No. 1 to No. 5 inclusive, Lower Coal Measures
No. 6, Crinoidal Lime, Middle Barren Measures
No. 7, Pomeroy, Pittsburg, Upper Measures

ON THE BALTIMORE & OHIO R. R.

No. 8, Great Limestone.
No. 9, Mauchsbury, Waynesbury.
No. 10, Gray Lime and Thin Coal, Upper Barren Meas.
No. 11, Constitution Stone, Grindstone grit etc.



GROUP No. 12.

INTERVAL BETWEEN THE BRADFORD "THIRD SAND" AND THE CORNIFEROUS LIMESTONE, commencing in the Chemung and including the Portage and Hamilton groups of the New York geological survey. Thickness, 1,600+ feet.

COMPOSITION.—In the imperfect records of wells that have been sunk into these measures in various parts of the country we simply find recorded "shales, slates, and soapstone, with occasional sand shells". The upper part for 200 or 300 feet appears to contain considerable sandy material, and some of these sand-beds produce oil along the Tuna valley, in the vicinity of Limestone, Cattaraugus county, New York. Below this the drillings show principally slate and soft-mud rocks. No important bands of sandstone and no oil have been reported.

The thickness of this interval must be left questionable for reasons previously stated. We have no means of tracing the corniferous limestone south of Fredonia, New York, except approximately by its slope.

The distance from Fredonia to Bradford is about 48 miles; direction about south 45° east. A dip of 20 feet to the mile would be required to place the limestone at Bradford as shown in our section.

GROUP No. 13.

THE CORNIFEROUS LIMESTONE, probably shown in the vertical section, Plate VIII, in conjunction with the ONONDAGA LIMESTONE.—The composition of this group has already been referred to in the quotations given from *Geology of New York*. It is the oil-producing rock of the Canadian oil regions, but at Fredonia, New York, yields neither oil nor gas. We may not presume, therefore, that it will ever be found to be an important oil horizon in Pennsylvania, and even if it should prove to be productive here the great depth at which it lies beneath the surface must be a very serious obstacle in the way of its development. (a)

An illustration of the persistence of the Venango oil group as a geological formation is found in the circumstances attending the drilling of well No. 1 by the Brady's Bend Iron Works Company in 1865. Professor J. P. Lesley was asked to give an opinion upon the probable depth at which oil would be reached on their property, and as he was familiar with the rocks of that locality, and had made a careful study of their dip and superposition, he readily made the computation and reported that "if the Venango sand extended under ground as far as Brady's bend it ought to lie at 1,100 feet beneath water-level". The well was drilled and struck the oil stratum at 1,120 feet.

During 1877 the so-called grasshopper excitement occurred near Titusville, occasioned by the discovery of oil in a layer of superficial gravel beneath a sheet of clay. The wells were simple pits or shafts, from which the oil and water were pumped. The area was comprised within a few acres, but was quite productive for a time, yielding several hundred barrels of oil. The oil evidently arose from deeper sources with water, and accumulated in the gravel beneath the impervious crust of clay.

The geology of the "West Virginia Oil Break" has been recently subjected to a very careful study by F. W. Minshall, esq., of Parkersburg, West Virginia. Mr. Minshall has been connected with the petroleum industry of this region for many years, and has carefully collated the records of many wells located along the line of development in Ohio and West Virginia. His sections are considered accurate by those most familiar with the facts and best qualified to judge of their value, and are found to conform strictly to such observations as I was able to make during a hurried trip through the region. I introduce here in illustration a series of sections compiled and drawn by Mr. Minshall and generously placed at my disposal for use in this report. The section on Plate iii extends along the axis of the anticlinal from the Ohio river opposite Newport, in Washington county, Ohio, to the Little Kanawha river, in Wirt county, West Virginia. Section 1 on Plate IV crosses section on Plate III at a point on or near the Ohio river in Washington county, Ohio. Section 2, Plate IV, crosses section on Plate III at Horseneck, Pleasants county, West Virginia. Section 3, Plate IV, crosses section on Plate III on the line of the Baltimore and Ohio railroad from Laurel Fork Junction to Petroleum, Wood county, West Virginia. Plate V is a vertical section of the rocks yielding petroleum along the anticlinal. Map IV shows the territory that has produced oil in the White Oak district which lies along the anticlinal between Goose creek and Walker's creek, Wood county, West Virginia.

The following description of the occurrence of the formations along the line of the White Oak anticlinal is taken from a series of articles published by Mr. Minshall in the summer of 1881 in the *State Journal* at Parkersburg, West Virginia:

In Wood, Pleasants, Ritchie, and Wirt counties the rocks, from the river level to the tops of the hills, belong to the upper barren measures, excepting only the line of territory known as the "oil break", which passes through these counties. Although we are very nearly in the center of the great Allegheny coal basin, we have no workable veins of coal above drainage in the above-named counties. The Allegheny basin is a veritable basin in form, which not only contains many valuable veins of coal, ore, and potter's clay, but also vast quantities of natural gas, petroleum, and brine.

On account of our situation near the center of the Allegheny basin, all the mineral wealth of its rocks is sunk beneath the river level. Here at Parkersburg, barely above the river, may be seen a thin vein of coal with an underlying vein of gray limestone. This we will call coal No. 11, and take it for our dividing line between the upper barren and upper productive coal measures. From the river to the top of fort Boreman, at the mouth of the Little Kanawha, we have an exposure of about 300 feet of the upper barrens. Examining them in detail, we will find them composed of alternate layers of red shale and compact, fine-grained sand rocks. The sand rock is of considerable value as a building-stone, being the same ledge as that which is extensively quarried between Belpre and Harmar, some parts of it furnishing grindstone grit and others the "Constitution" building-stone.

If, commencing at our coal No. 11 (see Plate V), we should sink a well, we would pass through the following strata: At about 150 feet we would reach the level of coal No. 10, the first vein of the upper productive measures, which has a thickness of from 4 to 6 feet

on Duck creek, in Washington county, Ohio; at 250 feet we should find coal No. 9, the limestone vein of Duck creek, and the equivalent of the Sewickly vein of Pennsylvania; at 350 feet we should pass the level of coal No. 8, the Federal creek vein of Athens county, Ohio, and the Pittsburgh vein of Pennsylvania, which is the last vein of the upper productive coal measures.

We next pass through the red and variegated shales of the lower barren measures, until at 500 feet we reach the crinoidal limestone. At 600 feet we will pass into a soft, pebbly sand rock, the first oil-rock of Cow run, Ohio; at 700 feet we should strike a hard, black, flinty limestone, several feet of very black shale, with white fossil shells and coal No. 7; at 730 feet, coal No. 6; at 800 feet, coal No. 5; at 850 feet another cherty limestone, probably the "Putnam hill" of the Ohio survey; at 880 feet, coal No. 4; at 900 feet we find another soft pebbly sand rock, the second oil-rock of Cow run, Ohio; at 1,000 feet, coal No. 3; at 1,070 feet, coal No. 2; at 1,200 feet coal No. 1; and at 1,300 feet, the top of the carboniferous conglomerate—the oil-rock of Lick fork and Tate run, in the White Oak district. (a)

These are the rocks through which we ought to pass in our Parkersburg wells. This prediction is based upon the fact that the uplift of the "oil break" brings this whole series of rocks above the level of the Ohio river in such a way that any one can examine them at his leisure and verify the intervals for himself.

Going back to our coal No. 11, with its underlying gray limestone, we will cross over into Ohio and trace it up the river on that side. At Marietta we find it coming up from the bed of the Muskingum near the "Children's Home". Keeping back from the Ohio river about two miles we see it in the bed of Duck creek at the old Robinson mill, in the bed of the little Muskingum at the mouth of Long run. We find very little change in the level of the stratum we are tracing till we are opposite the mouth of Cow creek. Here we find it gradually rising higher above the river as we go up the Ohio until, at the mouth of Newell run, on the Ohio side, we find it at the summit of the hill. Since it is evident that a farther rise will take it away from us, we must take our barometer and measure down the hill to coal No. 10; but instead of the 6-foot vein of Duck creek, we have here barely 2 feet; in fact, this vein thins rapidly southward from the maximum thickness at the upper line of Washington county, Ohio.

Having at the mouth of Newell's run substituted coal No. 10 for No. 11, we will go a little farther east until, opposite the mouth of French creek, we find coal No. 10 on the summit of mount Dudley. On mount Dudley we are standing on the axis of the anticlinal called the West Virginia oil break. Measuring down the face of the hill 100 feet from coal No. 10, we find coal No. 9, the limestone vein. Measuring again from coal No. 9 down the hill about 100 feet, we will find the proper horizon of coal No. 8, the Pittsburgh vein of Pennsylvania and the Pomeroy vein of Ohio. It is true that we will not succeed in finding any coal at this point; the overlying sand rock, a little fire-clay, and the underlying gray limestone are all we can find here; but before reaching the end of our journey we will find the coal putting in an appearance. The horizon of this vein is exposed from the Ohio river to the Little Kanawha along the axis of this anticlinal for a distance of about 30 miles, in which distance the coal increases from nothing to 20 inches. Measuring down from No. 8, 150 feet, we will find the crinoidal limestone of the lower barren measures lying about 40 feet above low-water mark. To show that we are upon the axis of the anticlinal, we will trace the limestone eastward along the face of the hill. For about a quarter of a mile we will find it running level, then dipping gradually to the east, until it disappears beneath the river. Returning, we trace it westward, and, after running level for the same distance, it dips to the west and goes under the river. At no other point in Washington county can this limestone be seen. (See Section 1, Plate IV.)

Having thus satisfied ourselves that we have reached the axis of "the break", our purpose is to follow this axis to the point where it crosses the Little Kanawha above Burning Springs, West Virginia.

Starting out from mount Dudley (see Plate III), we bear several degrees west of south, cross the Ohio a little below French creek, in Pleasants county, cross McElroy run at Ned Hammett's, and strike the north hillside of Cow creek near the residence of Hugh McTaggart, esq. In a hollow north of the house, and about on a level with it, we find the crinoidal limestone. Continuing our course, but bearing more nearly south, we cross Cow creek below the old "Willard" mill, the head of Calf creek, near William Nash's, and reach a high point on the north side of Horseneck. On the very summit, by searching carefully, we will find, as though it had been placed there for our especial benefit, the crinoidal limestone about 580 feet above the river. To satisfy ourselves that the anticlinal maintains its form, and that we are still upon its axis, we trace the limestone westward till it dips beneath the bed of Calf creek, near the new school-house, and eastward into the bed of Sled fork of Cow creek; and we notice that the dip is getting steeper on the sides as the axis rises, but no signs of faulting or displacement of the strata are to be found. (See Section 2, Plate IV.) Our crinoidal limestone, which was 500 feet below the river at Parkersburg, is now 580 feet above, having risen 1,080 feet, and, like coal No. 11, having reached the summit of the highest hills, will soon be beyond our reach if the axis continues to rise. We will therefore take the precaution to measure down to some of the lower strata. One hundred feet below the crinoidal lime we find another massive sand rock similar to the one which lies over coal No. 10. Like that, it is a true conglomerate, with layers of quartz pebbles somewhat similar and whiter than those of No. 10. It is the first oil-sand of Cow run and Macksburg, in Washington county, of Buck run, in Morgan county, and of Federal creek, in Athens county, Ohio, easily identified by the interval being about 100 feet in all of the above-named places. At its outcrop at the head of Calf creek it forms a bold ledge, which at one point is broken into huge cubical blocks of about 30 feet in thickness, forming a "rock city" similar to the one near Olean, in New York.

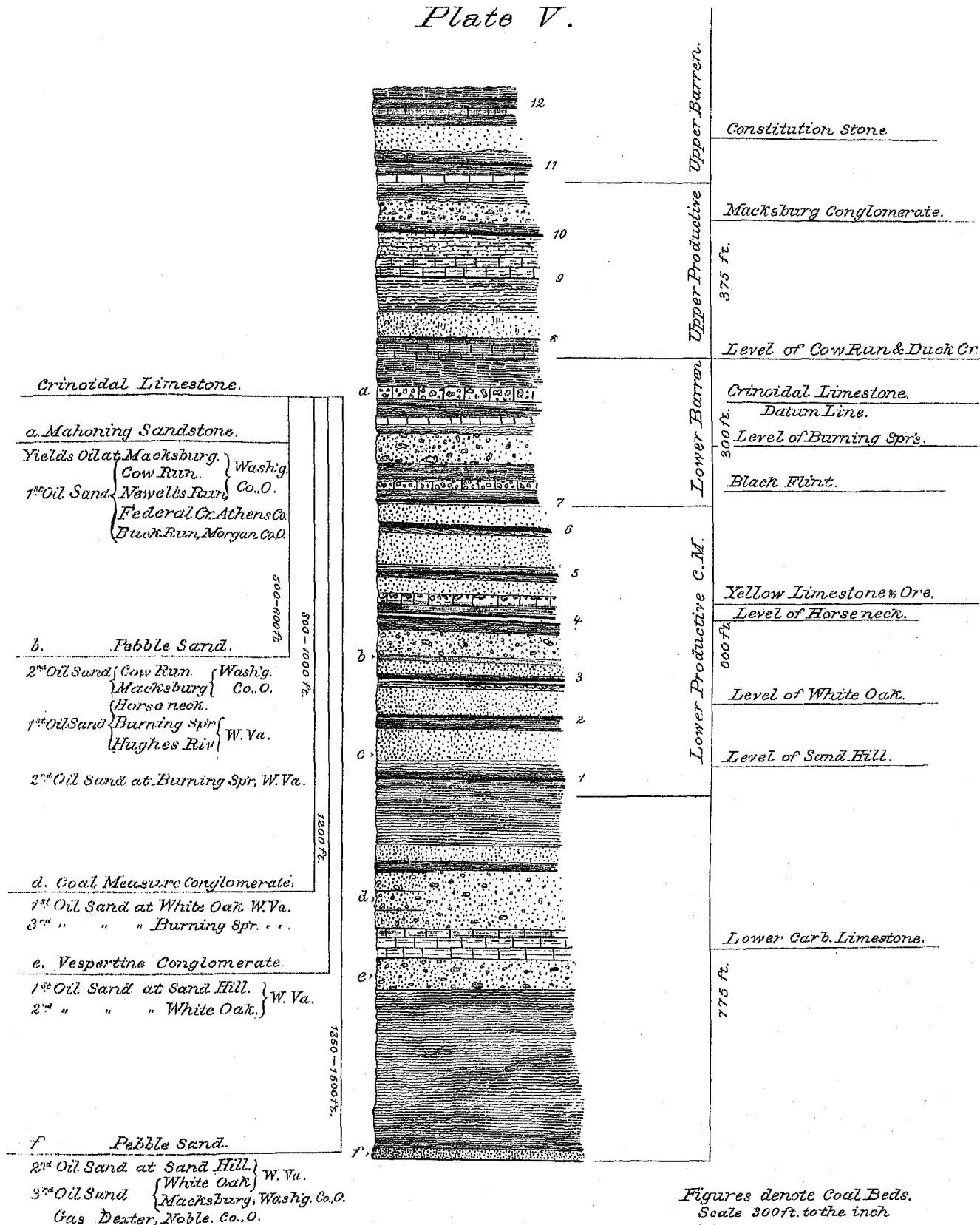
Below this sand rock, and about 200 feet below the crinoidal lime, we find coal No. 7. Although the coal is only 18 inches thick, this vein becomes interesting because of its surroundings. Just over the coal is a stratum of very black shale, about 10 feet thick, filled with fossil shells. Over the shells is a black, flinty limestone, which we will find increasing in thickness southward until it becomes the well-known flint vein of Hughes river and Flint run.

From Horseneck we resume our course, crossing Bull creek near the celebrated mineral well of Judge Borland. In the bed of the run, a short distance above Judge Borland's well, we find the crinoidal limestone. Careful inspection shows us that we are still following the axis of the anticlinal, and that it has come down on the south of Horseneck even more rapidly than it had risen on the north. This will, when examined, prove to be a regular dip along the axial line, without any indications of faulting, and the dip continues until the gray limestone of No. 8 is brought down to the bed of the run; then the dip is suddenly reversed, and the axis rises again to the southward. From this point to Sand hill, on Walker's creek, the rise is very rapid, bringing to the surface in regular succession the rocks above described down to the yellow limestone. This we follow in its upward course till it reaches the top of the high point near the Saint Ronan wells of White Oak district. Looking around us from this vantage-ground we will notice that although the distant hills preserve their graceful outlines the surrounding hills are mostly cone-shaped peaks, bristling with an unnatural kind of timber, the rig timber of the oil-seeker. In prosperous times, when clouds of smoke were pouring forth from hundreds of sooty craters and the clang of tools rivaled the din of old Vulcan and his cyclopic helpers, some genius, in a moment of inspiration, christened the place Volcano.

On the top of the high peak near Saint Ronan's well we will examine the limestone, which lies within 25 feet of the summit. We have assumed this vein to be the equivalent of the "Putnam hill" vein of the Ohio survey; it is also the only vein we will find which might be taken to represent the "Ferriferous limestone" of Pennsylvania; it lies here a few feet above coal No. 4. Examining the

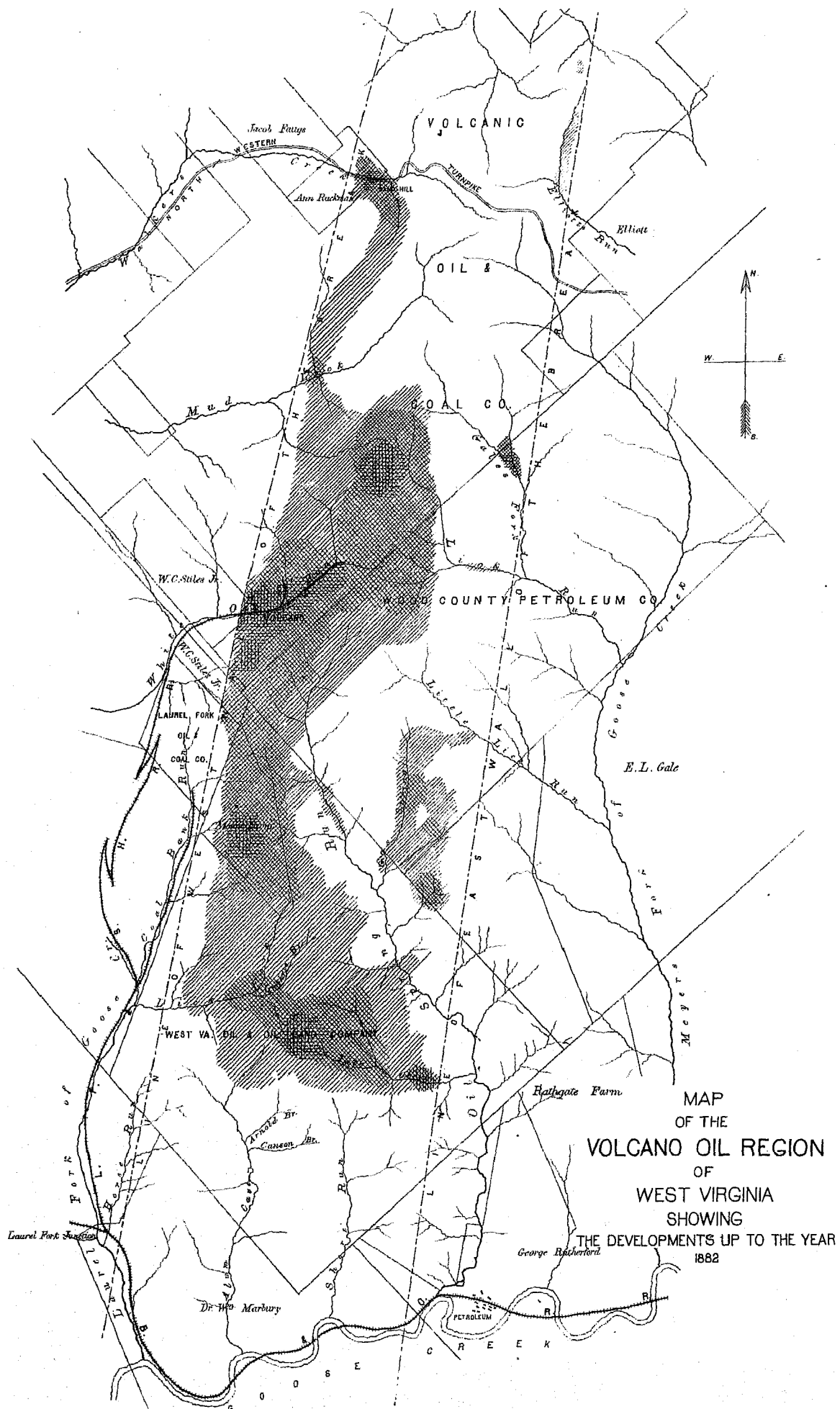
a Also of Johnson county, Kentucky.

Plate V.



VERTICAL SECTION OF WHITE OAK ANTICLINAL WEST VIRGINIA.

Compiled by F. W. Minshall, Marietta O.



structure of the vein, we find that it is deposited in large, round boulders, from one to three feet in diameter. The upper layers are heavily charged with iron, showing, when exposed to the weather, a very rusty yellow. A peculiar feature of the ore-bearing boulders is their formation in regular concentric layers. If one of them be broken through the center you may see, from center to circumference, the rings as regular as the rings of a cross-section of a tree. As the boulder becomes oxidized these rings peel off successively, leaving its form unchanged. The identification of this vein as the equivalent of the "Ferriferous" would be of great value to us for the purpose of comparing the geological level of our oil-bearing rocks with those of Pennsylvania.

Resuming our measurements from this limestone downward we will find, 30 feet below it, coal No. 4; 160 feet below the lime, coal No. 3; and 230 feet below the lime, coal No. 2. With this vein is a hard, black slate, about a foot thick, which is always piled in masses around the mouth of the mine, and is sometimes called "bone-coal". These measurements can be made to the best advantage by going down the south side of the hill into the hollow on the Saint Ronan lease, in which coal No. 2 is mined, all the points of exposure being on the central axis and as nearly vertical as is possible to find them.

In order to get a good exposure of the limestone for examination, we came beyond the highest point in the axial line. We will therefore retrace our steps for about a mile northward. This will bring us to "Sand hill". Here we find coal No. 2 about 170 feet above Walker's creek, and the horizon of coal No. 1 about 40 feet above the bed of the stream. In lieu of coal we shall have to content ourselves with the thick bed of fire-clay, which is a persistent accompaniment of it in Ohio. Assuming the bed of Walker's creek at this point to be 250 feet above the level of the Ohio river, we have, from the river level up to coal No. 1, 290 feet, plus interval from coal No. 1 to yellow limestone, 360 feet, plus interval from yellow lime to crinoidal lime, 350 feet, plus interval from crinoidal lime to coal No. 11, 350 feet, equal to 1,500 feet, the total amount of uplift to the highest point. Add to this 500 feet of the upper barren measures, which may be seen in the surrounding hills, and deduct the 250 feet which lie below the bed of Walker's creek, and we have 1,750 feet of coal-measure rocks fairly exposed within an area of a few miles, which any student of geology may study at his leisure.

We will now go back to Sand hill and resume our journey southward (see Map IV). Crossing White Oak fork of Walker's creek above Volcano, we keep along the ridge, with Coal Bank run and Rogers gulch on our right and Oil Spring run, with its branches, on our left, till we come to the dividing ridge between Lick fork and Tate run; here we halt and look around us. From Sand hill to this point we have passed through the center of the White Oak producing territory, a strip along the central axis of the break about four miles long and one mile wide, on which there are something like 600 wells now working. The southern end, at which we have stopped, is now the busiest part.

Glancing down at our feet we will see that we are standing upon a soft, yellow sand, filled with pebbles about the size of a pea; some of them have a delicate blue tinge, but most of them are of a very clear white, almost translucent. This is the second oil-sand of Cow run, Ohio, from which a single well has produced \$200,000 worth of oil.

Here there is just as much attention paid to the oil-rock proper as in any other territory. The only peculiar feature about the territory is the fact of its being located on the crest of a well-marked anticlinal, and whether you will find an accumulation of gas, oil, or water in the rock depends upon the comparative level of the point at which you strike a fissure. The statement which Professor Stevenson makes concerning the form of the "break" at Hughes' river along the Staunton pike is accurate and true for the whole length of the line; "there is no evidence of faulting on either side. The succession from the inner portion of the abruptly-tilted strata outward to the horizontal strata is unbroken and perfectly clear. Within the 'break' the rocks are almost horizontal and not much broken. They describe a flattened anticlinal". That this statement is true of the most disturbed portion of the whole line we may see for ourselves. Starting from the point at which we halted, we will go down on to Lick fork. From this point the stream runs nearly west to its junction with Laurel fork. About 40 feet above the bed of the stream we will find coal No. 2 lying horizontal. Following it westward down the run, we find that it soon begins to dip gradually, and in the course of a few rods comes down to the bed of the stream. Just before it disappears we see that it is beginning to dip at a much steeper angle, but shows no displacement. As we continue down the stream we find that we are passing over the upturned edges of the strata, but everything is in its proper place. Coal No. 3, the pebbly sand-rock that lies above it, the yellow limestone, the black flint, the crinoidal limestone, and the gray limestone of the Pittsburgh vein, each is seen in its legitimate position, the intervals being comparatively the same as when we measured them vertically. Laurel fork, from the mouth of the Lick fork to the Baltimore and Ohio railroad, runs very nearly parallel with the axis of the break. Placing the compass upon the upturned edge of the crinoidal limestone, where it is exposed in the bed of the run, we see that it runs straight as a line S. 10° W. Being only 18 inches in thickness, it serves us admirably as an indicator of the course of the break. The black flint and the gray limestone, when tried by the compass, show the same course. From the mouth of Lick fork to the railroad this gray limestone of the upper productive coal group may be traced. Standing almost vertically, it crosses the railroad in the bed of the stream between Laurel junction and the first cut to the west. In this cut the double vein of coal No. 9 of the upper measures shows dipping at a sharp angle to the west. At the west end of this cut the dip becomes more gradual, but continues until the rocks of the upper coal group, including our No. 11, are brought down to the level of the railroad. If we should go eastward from Laurel junction to Petroleum we should find the same state of facts existing that we have just enumerated; in the beds of Oil Spring run and Goose creek all of our well-known rocks, from coal No. 2 to coal No. 11, dipping to the east complete the symmetry of the anticlinal. (See Section 3, Plate IV.)

From the head of Lick fork the axis of the break commences to dip southward. Following the axial line we cross the northwestern branch of the Baltimore and Ohio railroad about midway between Laurel junction and Petroleum, cross the head of Ellis run and along Dry ridge to William Sharpneck's, on the north side of Hughes' river. Near the school-house on Dry ridge may be seen a fine exposure of the crinoidal limestone, here 350 feet above the bed of Hughes' river, showing a southern declination of about 550 feet between this point and the highest point of the axis at Sand Hill. About 200 feet below the crinoidal limestone is the flint vein. The same black shale, filled with white fossil shells, that underlies it at Horseneck is found here, affording a sure means of identification.

Resuming our journey southward, we cross Hughes' river near the old Walton Wait well, climb the steep hill on the south side, and keep along the ridge with the waters of Island run on the west and of Flint run on the east, until we come to the head of Wilson's branch of Parish fork. From Dry ridge to this point we find the crinoidal limestone lying about level; from this point it commences to dip southward. We follow the course of Wilson's branch down to within a few rods of the old Parmenter well, then over the ridge, cross Parish fork above the residence of Mr. Fred. Bailey, cross oil-rock near the old "Orchard" well and the main branch of Standing Stone creek at the Fisher farm. Here we find the crinoidal limestone just 30 feet above the bed of the creek. Total southern dip from Sand hill to Standing Stone, 850 feet. The dip has now been sufficient to bring the soft pebbly sandstone which lies over coal No. 10 into the hills. Going westward down the creek, we may see this ledge of rock, about 40 feet thick, running like a wall from the bed of the stream to the top of the hill.

At Standing Stone the south dip is reversed and the axis rises. Following the line, we cross Dever's fork at David Dever's, where we find the crinoidal limestone 150 feet higher than at the Fisher farm. Continuing our course, we cross the head of Chestnut run, keep along the ridge with the headwaters of Upper Burning Spring run to the east and Nettle run to the west of us, and strike Lower Burning

Spring run near the Newberger and Braidon well. Here we find the crinoidal limestone 125 feet above the Little Kanawha river, making 800 feet in geological level between this point and the head of Walker's creek at Sand hill. The bed of the stream at Walker's creek being 200 feet higher than the bed of the Little Kanawha makes the difference in drilling for any given rock about 600 feet. * * *

At Burning Springs the axis again commences to dip southward, and at the point where it crosses the Little Kanawha, a short distance above the mouth of Spring creek, the crinoidal limestone is 60 feet below the bed of the river.

Our investigation shows that the White Oak anticlinal or "oil break" is a fold or wrinkle in the bottom of the great trough called the "Allegheny coal basin", extending from a point about 4 miles north of the Ohio river to a point about the same distance south of the Little Kanawha at Burning Springs; that there are undulations in the axial line which divide the line into three sections, which, had there been no erosion of the surface, would have presented three peaks of different altitudes; that of Horseneck would have been about 500 feet higher than that of Burning Springs, and that of White Oak about 300 feet higher than that of Horseneck, and the summit of the White Oak peak would have been about 2,000 feet above the level of the Ohio river. Under each of these peaks the rocks lie in the form of a table, say four miles long and from three-fourths to one mile wide. From the ends and sides of these tables the rocks dip at certain angles. Taken as a whole, the rocks form inverted basins, with flat bottoms and sloping sides. In these inverted basins nature for thousands of years had been collecting gases as the chemist collects them in inverted bottles over the pneumatic cistern. At Burning Springs the accumulation of gas became so large that it forced its way through the fissures of the overlying rocks to the surface, forming a natural gas-spring, which often became ignited and burned for days on the surface of the water through which it was escaping.

All of the work done in this region prior to 1864 was done without recognizing the fact that the territory was confined to the crest of an anticlinal, and large sums of money were expended in the purchase of territory and drilling of wells along the margins of other streams in the neighborhood. The operators also remained ignorant of the fact that two of the producing rocks of White Oak lay beneath the conglomerate. The escape of the gas at the summit of the other inverted basins drew the attention of operators to Horseneck and White Oak (from Burning Springs). About the year 1865 General A. J. Warner and Professor E. B. Andrews, of Marietta, became interested in White Oak territory, and these gentlemen soon began to draw geological inferences which led to an abandonment of the old policy of following the beds of the streams and to a recognition of the fact that the oil was confined to the crest of an anticlinal; hence the White Oak section, and that alone, has been thoroughly and systematically worked. After it had been clearly recognized that the oil territory was confined to the crest of the anticlinal, it was somewhat hastily inferred that the crest would be valuable territory for its entire length, and many test wells were drilled on the strength of this inference. These test wells showed such a large percentage of failures that, three years ago, the writer undertook to account for them by making a careful level along the entire length of the axis. The undulations of the rocks shown by the profile (Plate III), taken in connection with the known laws of hydrostatic pressure, satisfactorily account for the failures, and show that part of the crest of the anticlinal is filled with an accumulation of water, and also what part must contain the accumulation of oil and gas.

Taking into consideration our position in the trough of the Allegheny basin, and the fact that on all sides of us the conglomerate is filled with brine, as on the Allegheny river above, at Pomeroy and Charleston below, on the Big Muskingum to the west, and the head of the Little Kanawha to the east, at all of which points it lies at a higher level than it does in the counties through which we have passed, we may safely conclude that the productive oil territory of West Virginia must be confined to the summit of the anticlinals or local rolls similar to the White Oak line.

The question has been raised by some of the Pennsylvania geologists as to whether rocks lying below sea-level can be expected to contain an accumulation of oil. In 1878 the writer drilled a well at Dexter, Noble county, Ohio, in which he struck a sand-rock about 700 feet below sea-level, containing a large accumulation of dry gas, and in the succeeding year George Rice, esq., obtained at Macksburg, Ohio, a flowing well from the same rock at the same level. The writer's well at Dever's fork, in Wirt county, also contains a large accumulation of gas and some oil in the Vespertine sandstone 300 feet below sea-level. This question is mentioned here because all of the Pennsylvania oil-bearing sands, if here at all, would lie several hundred feet below tide-water, even on the crest of our White Oak anticlinal.

CONCLUSIONS.

I have quoted Mr. Minshall's work in great detail, and have introduced all of his sections, for the purpose of showing the facts from which his conclusions have been drawn. His facts were ascertained after many a mile of tramping and careful barometrical measurement; a work far more laborious and valuable than that of collating the records of wells, which, though sometimes correct, are more often defective through ignorance or inattention. Mr. Carll has tramped over the hills and through the forests of northwestern Pennsylvania to gain personal knowledge of the region, and his work has high value in the eyes of the oil producers. Both Mr. Minshall and Mr. Carll have learned the geology of petroleum at the edge of the drill, barometer in hand, both of them seeing and handling what they describe.

Assuming that Messrs. Hunt, Carll, and Minshall have observed correctly and stated their observations correctly, petroleum occurs in crevices only to a limited and unimportant extent. It occurs saturating porous strata and overlying superficial gravels; it occurs beneath the crowns of anticlinals in Canada and West Virginia, and does not occur in Pennsylvania; but in the latter region it occurs saturating the porous portions of formations that lie far beneath the influence of the superficial erosion, like sand-bars in a flowing stream or detritus on a beach. These formations or deposits, taken as whole members of the geological series, lie conformably with the inclosing rocks, and slope gently toward the southwest. The Bradford field in particular resembles a sheet of coarse-grained sandstone, 100 square miles in extent by from 20 to 80 feet deep, lying with its southwestern edge deepest and submerged in salt water and its northeastern edge highest and filled with gas under an extremely high pressure.

It is further to be concluded that, from whatever source the petroleum may have originally issued, it now saturates porous strata, not of any particular geological age, but runs through a vast accumulation of sediments from the oldest to the newest rocks, in Pennsylvania and West Virginia embracing all of the rocks between the Lower Devonian and the Upper Carboniferous.

CHAPTER IV.—THE CHEMISTRY OF PETROLEUM.

SECTION 1.—THE CHEMISTRY OF CRUDE PETROLEUM.

The wide distribution of bitumen in nature has already been noticed. As early as 1823 the Hon. George Knox called attention to its prevalence in rocks and minerals, and showed that, along with lithia and fluorine, it had been overlooked in their analyses. (a) The following year Vauquelin published a notice, with an analysis of the bitumen contained in the sulphur of Sicily. (b) In 1837 Boussingault published the results of an examination of the bitumen of Pechelbronn and other bitumens of southern Europe, which for many years was considered a classic upon the subject. (c) In 1853, Dr. C. Völckel examined the asphalt of the Val de Travers. (d) These analyses of solid bitumens were mainly attempts to determine the constitution of these materials by ultimate analysis, and were very valuable at the time they were made.

The first research upon fluid bitumen or petroleum was made by Vauquelin in 1817 upon the naphtha of Amiano, which at that time was used in street lamps in the small towns of the duchy of Parma. (e) In 1857, Engelbach examined the petroleum sand of the Luneberger heath, in Holstein, which has lately been attracting so much attention; (f) and Warren de la Rue and Hugo Miller worked on several tons of Rangoon tar or Burmese petroleum, and distilled the oil with steam at 100° C. and with steam superheated to 200° C., and examined the distillate. (g)

American petroleum was examined by Professor Benjamin Silliman, sen., in 1833, (h) and by Professor B. Silliman, jr., in 1855, who published his results in his celebrated report on the petroleum of Venango county. (i) Since petroleum became an article of commerce innumerable examinations from all parts of the world have been made for technical purposes. These examinations have been chiefly made with reference to determining the amount of distillate available for illuminating purposes. In the earlier period of the commercial production it was assumed that petroleum from different localities were identical, except in specific gravity, and that therefore the distillate of the same specific gravity possessed the same properties. Professor B. Silliman, jr., and myself examined the petroleum of California; (j) H. St. Claire Deville and others those of Java, Pennsylvania, and Russia; (k) Ravaset examined Trinidad pitch, (l) Waller the petroleum of Santo Domingo, (m) and Silvestri the petroleum-like constituents of the lavas of Etna. (n) The distillations essential to these analyses were often conducted in an ordinary glass retort, or with an alembic. Of the two, the alembic is very much to be preferred, as its use prevents the cracking of the oils. In 1868 Dr. H. Letheby contrived an apparatus for this purpose, which is described in the *London Journal of Gas Lighting*, xii, 653. In 1866 Dr. John Attfield published a description of another, (o) and the following year I described an apparatus of my own invention for the technical analysis of petroleum or solid bitumens, either with or without pressure. (p)

The ultimate analysis of petroleum early showed it to consist of carbon and hydrogen. It was for a long time assumed that crude petroleum contained an equal number of atoms of these elements, but my own examination of Californian and other petroleum in 1867 and 1868 (q) showed that the first named variety contained from 0.5645 to 1.1095 per cent. of nitrogen; that Mecca (Ohio) oil contained 0.230 per cent., and oil from the Cumberland well, West Virginia, 0.54 per cent. of the same element. Determinations of the hydrogen and carbon in several samples of petroleum showed that the proportion of carbon increases with the density. The following table shows the percentage of composition of the several different varieties: (r)

	Hydrogen.	Carbon.	Nitrogen.
Scioto well, West Virginia.....	12.929	86.022	.....
Cumberland well, West Virginia.....	13.359	85.200	0.5400
Mecca, Ohio.....	13.071	86.216	0.2300
Hayward Petroleum Company, California.....	11.819	86.934	1.1095
Pico spring, California.....	.....	.....	1.0165
Cañada Laga, California.....	.....	.....	1.0855
Maltha, Ojai ranch, California.....	.....	.....	0.5645

a *Phil. Trans.*, 1823; *Phil. Jour.*, ix, 403; A. J. S. (1), xii, 147.

b *Ann. de Chim. et de Phys.* (2), xxv, 50.

c *Ibid.*, lxiv, 41; New Ed. *Phil. Jour.*, 1837.

d *Ann. der Chem. u. Pharm.*, lxxxvii, 139.

e *Ann. de Chim. et de Phys.* (2), iv, 314.

f *Ann. der Chem. u. Pharm.*, ciii, 1.

g *Phil. Mag.* (4), xiii, 512.

h *Am. Jour. Sci.* (1), xxiii, 97.

i *Am. C.*, ii, 18.

j A. J. S. (2), xxxix, 341; (2), II, xliii, 242; C. N., xvii, 257;
Geo. Surv. of Cal.: Geology, ii, Appendix, p. 49.

k *U. S. et Ind.*, 1871, 146.

l *Jour. de l'E. au gas*, 1872; *A. Chem.*, ii, 316.

m *Am. Chem.*, ii, 220.

n *Gaz. Chim. Ital.*, vii, 1.

o *Chem. News*, xiv, 98.

p A. J. S. (2), xlv, 230; C. N., xvi, 199.

q *Rep. Geo. Surv. Cal.*: Geology, II, Appendix, pp. 84, 89.

r *Ibid.*, p. 89; *Am. Chem.*, vii, 327. The methods of analysis used to meet the peculiar difficulties presented by these substances is fully described in both the works referred to.—S. F. P.

Delesse notes 0.154 per cent. of nitrogen in elalerite and 0.256 per cent. in the bitumen from the pitch lake of Trinidad. (a)

O. Hesse has shown the presence of sulphur in Syrian and American asphalt to the amount of 8.78 and 10.85 per cent., respectively, and one sample of California petroleum examined by myself contained a sufficient amount of sulphur to form a deposit in the neck of the retort. It is well known that Canada petroleum contains sulphur, but the Pennsylvania and West Virginia oils are remarkably free from it. A qualitative test for sulphur in petroleum is described on page 181. An oil is described from the Kirghish steppe said to contain 1.87 per cent. of sulphur and to be purified with great difficulty. According to Mr. John Tunbridge, gold may be found in the ashes of crude petroleum and in the refuse of petroleum stills, and he is reported to have extracted \$34 worth of gold from a ton of residuum, the source of which is not given. (b)

In general, it may be stated that the ultimate analysis of petroleum shows it to consist of carbon and hydrogen, with a very small proportion, in some instances, of nitrogen, sulphur, and perhaps oxygen. Metallic arsenic is said to condense in the goose-neck of the retorts in which the bituminous limestones of Lobsan are distilled. (c)

SECTION 2.—THE PROXIMATE ANALYSIS OF PETROLEUM.

In 1824 Reichenbach published his researches upon paraffine and eupion, (d) and ten years later published a paper upon petroleum or rock-oil; (e) and he appears to have been the first chemist who attempted a separation of the definite chemical compounds that are mixed together in petroleum and similar liquids. Further attempts were made at their separation by Laurent, (f) but, as might be expected, they were only partially successful, as the eupion and other liquids obtained by Reichenbach and Laurent were for the most part mixtures still.

In 1863 Schorlemmer, in England, and Pelouze and Cahours, in France, published researches upon American petroleum, which were really the first successful attempts to isolate any number of the constituents of this complex mixture of substances. Schorlemmer showed that American petroleum contained in the portion boiling below 120° C. the same hydrides as are obtained from the distillate from cannel coal, (g) but Pelouze and Cahours determined American petroleum to consist of the homologues of marsh-gas. The lowest determined by them was hydride of butyl, C_4H_{10} , which boils a little above 0° C., while the highest had a composition of $C_{30}H_{62}$. They considered paraffine a mixture of still higher terms, and regarded the small quantity of benzole and toluole alleged to have been obtained by Schorlemmer to have been due to destructive distillation of the petroleum. (h)

At the same time that the researches just mentioned were being carried on in Europe, C. M. Warren, alone and associated with F. H. Storer, was engaged on a similar research in this country. (i) The results obtained by them were published in 1865 and 1866, and while in the main confirmatory of those previously obtained, they were in many respects superior in point of definiteness and accuracy, from the fact that Warren used an apparatus for separating his material greatly superior to any hitherto employed. (j) In discussing the identity of the compounds obtained by himself and MM. Pelouze and Cahours, Warren remarks that he considers vapor density and analysis as corroborative evidence with boiling point; but aside from such evidence, he regards the superiority of his process of distillation as a paramount means of securing pure products for analysis, and therefore entitled to great consideration. (k)

Warren succeeded in isolating fourteen different liquids in quantities of several hundred cubic centimeters, and so pure that the whole quantity might be distilled from an ordinary tubulated retort within a range of temperature of 1° C. He was consequently enabled to determine their boiling points with great accuracy, and hence the difference in their boiling points, to analyze them and determine their vapor density and establish their formulæ. The composition assigned by him to the fourteen compounds is given in the following table:

FIRST SERIES.		SECOND SERIES.		THIRD SERIES (not completed).	
Formula.	Boiling point.	Formula.	Boiling point.	Formula.	Boiling point.
	Degrees.		Degrees.		Degrees.
C_4H_{10}	0.0 ?	C_4H_{10}	8—9	$C_{10}H_{22}$	174.9
C_5H_{12}	30.2	C_5H_{12}	37.0	$C_{11}H_{22}$	195.8
C_6H_{14}	61.8	C_6H_{14}	68.5	$C_{12}H_{24}$	216.2
C_7H_{16}	90.4	C_7H_{16}	98.1		
C_8H_{18}	119.5	C_8H_{18}	127.6		
C_9H_{20}	150.8				

a *De l'Azote et des Matières dans l'Ecorce Terrestre.*
Paris, 1861, pp. 172, 173.

b J. F. I., cix, 175.

c *Ann. des Mines* (4), xix, 669.

d *P. Mag.* (2), i, 402.

e *Schweig. Seid. Jour.*, ix, 133; *P. Jour.*, xvi, 376.

f *Ann. Chim. et de Phys.* (2), lxiv, 321.

g *Proc. Manchester Phil. Soc.*, March 11, 1863; *A. J. S.* (2), xxxvi, 115.

h *Ann. C. et P.* (4), i, 5.

i *Mem. Am. Acad.*, N. S., ix; *Am. J. Sci.* (2), xl and xli.

j *Mem. Am. Acad.*, N. S., ix, 121; *A. J. S.* (2), xxxix, 327.

k *A. J. S.* (2), xlv, 262.

I have changed the atomic value of 12 given in Warren's memoir to that of carbon=6, as at present used, in order that these formulæ may be more readily compared with others. Warren does not give the specific gravity of his compounds, nor does he give any hint regarding the relative proportions of these compounds in crude petroleum, and his work was qualitative as regards the crude oil. Messrs. Warren and Storer also examined Rangoon petroleum, with the following result:

	Deg. C.
Rutylene, $C_{10}H_{20}$, boiling at about	175
Margarylene, $C_{11}H_{22}$, boiling at about	195
Laurylene, $C_{12}H_{24}$, boiling at about	215
Cocinylene, $C_{13}H_{26}$, boiling at about	235
Naphthalin, $C_{10}H_8$	—

Also, probably, pelargonene = C_9H_{18} , boiling at about 150° , and members of one or both the series of hydrides (from American petroleum), it being a fair presumption that we have had in our hands hydrides of α -naphthyl (C_7H_{10}), of capryl (C_8H_{18}), and of polargonyl (C_9H_{20}). Our experiments also indicate the probable presence of xylene and isocumole. (a)

The latter, with naphthaline, are found in coal-tar.

It will be noted that these researches were had only upon the more volatile portions of the petroleum, without regard to the more dense portions with high boiling points, and that they established the fact that the more volatile portion of American petroleum contained principally the homologues of marsh-gas, with the general formula C_nH_{2n+2} , and also the homologues of olefant gas, with the general formula C_nH_{2n} , and that the corresponding portion of Rangoon petroleum contained principally the homologues of olefant gas, the benzole series, and probably some of the higher members of the marsh-gas series.

An examination of paraffine and its chemical relations showed that it was one of the higher homologues of marsh-gas, hence the English chemists have called the whole series paraffines, including the solid, liquid, and gaseous members.

During 1865 E. Ronalds isolated butyl hydride from American petroleum and described it as a liquid with a specific gravity of 0.600 at 32° F.; vapor density, 2.11, colorless, and of a sweet taste and agreeable odor. Alcohol of 98 per cent. dissolves from eleven to twelve times its volume. (b) The same year Tuttschew discovered the homologues of olefant gas (C_nH_{2n}) in illuminating oil from Galician petroleum. (c)

Since 1865 up to 1880 the paraffines of American petroleum have been the subject of a vast amount of research, particularly by English chemists. Goldstein, (d) Stenhouse, (e) Odling, (f) Herman, (g) Morgan, and Schorlemmer (h) have all contributed to the mass of knowledge relating to this subject that is now the possession of chemists. Pre-eminent, however, among these investigators is the name of Schorlemmer; but it would be impossible to give here a *résumé* of his results that would be understood by the general reader; in fact, many of his most elaborate researches are of a purely scientific nature. His numerous papers will be found in the *Philosophic Transactions* and the *Journal of the Chemical Society*.

Very little has been done upon Canadian petroleum. Schorlemmer has shown that the benzole series is present in it. (i) Russian petroleum has been examined by Beilstein and Kurbatow (j), and they found that the more volatile products of Caucasian petroleum consist of the additive compounds of the benzole series, having a higher specific gravity for the same boiling point than the compounds constituting American petroleum and containing more carbon. Further experiments, undertaken to ascertain if American petroleum contained these bodies in small proportion, yielded negative results, all of the derived compounds showing the presence of the alcohol radicals (C_nH_{2n+2}), and not of benzole or its additive compounds. The relation which these additive compounds sustain to benzole may be inferred from the following formulæ:

Benzole.....	C_6H_6	Hexahydro benzole.....	C_6H_{12}
Toluole.....	C_7H_8	Hexahydro toluole.....	C_7H_{14}
Isoxylene.....	C_8H_{10}	Hexahydro isoxylene.....	C_8H_{16}

Schützenberger and Jonine having also examined Caucasian petroleum, (k) found a notable fraction of the light oil to consist of the isomers of ethylene (C_nH_{2n}). Their results confirm in a general way those obtained by MM. Beilstein and Kurbatow.

The liquids which form the heavier portions of petroleum, from which paraffine crystallizes, have not as yet been very fully examined. For some time it was questioned whether paraffine was a constituent of Pennsylvania petroleum, and those who maintained that it was not accounted for the fact that it sometimes crystallized from crude petroleum by assuming that such petroleum had been heated since it escaped from the wells. The phenomena attending the occurrence of petroleum in the Bradford district has, however, removed this question from all future

a *Mem. Am. Acad.*, ix.

b *J. C. Soc.* (2), iii, 54; *Bul. de la S. Chim.*, 1866, 135.

c *Jour. f. Prak. Chem.*, xciii, 394; *Bul. de la S. Chim.* 1865, ii, 229.

d *J. C. S.*, xxxvi, 765; *B. D. C. G. B.*, xii, 689.

e *B. S. C. de P.*, 1878, 189; *Ann. der Chem.*, clxxxviii, 249.

f *Proc. Roy. Inst.*, viii, 16.

g *Rep. B. A. A. S.*, 1875.

h *J. C. Soc.*, xxviii, 3011.

i *C. N.*, xi, 255; *Trans. Roy. Soc.* (5), xiv, 168.

j *B. D. C. G. B.*, xiii, 1818 and 2028; *A. J. S.* (3), xxi, 67 and 137.

k *B. D. C. G. B.*, 1880, 2428; *Bul. S. C. P.*, 1880-2, 673.

controversy, as there paraffine is shown to be susceptible of fractional condensation, the extremely low temperature, consequent upon the removal of the enormous pressure, causing the more dense paraffines to condense in the pipes, leaving a large content of those with higher melting points still dissolved in the oil. It now appears to be firmly established that paraffine as at first isolated is not a homogeneous body, but a mixture of several homologous, perhaps isomeric, bodies having similar properties, but different boiling points. For the history of the discovery of paraffine and a description of the principal researches that have been conducted upon it, see the chapter on Paraffine in Part II of this work.

Recently the constituents of residuum have been made the subject of careful study. Professor Henry Morton, of the Stevens Institute of Technology, first called attention to these substances. Speaking of the distillation of "residuum" for the production of paraffine and lubricating oils, he says:

At the end of this operation, when the bottom of the still is already red-hot and some coke has been formed, there runs very slowly from the condenser a thick, yellow-brown tar, which is almost solid in cold weather, and in summer is only semi-fluid. * * * This thick tar, prior to 1873, was only used as a lubricant for the necks of rolls in rolling-mills, its great tenacity securing its adherence under the very unfavorable conditions to which it was there exposed. About March, 1873, however, Mr. John Truax, of Pittsburgh, wrote me as follows, referring to this tar: "Within a few months we have found a new use for it in the manufacture of a lubricating oil." * * * Returning to the production of what may be termed "thallene tar", I cannot do better than quote part of a letter received from Mr. Truax: "This material (referring to the thallene tar) drains or drips from the end of the pipe forming part of the condenser after all the tar has been distilled, and is in reality the product of the distillation of the petroleum pitch remaining in the still. Tar of petroleum (residuum), which we use exclusively, of gravity 20° Baumé (specific gravity 0.936) or thereabouts is distilled in cylindrical stills or retorts set vertically. These are 9 feet in diameter, and from 3 to 4 feet high. The condensation is effected in the usual manner. The stills are inclosed in brick work all around the sides, forming a flue, through which all the products of combustion in the furnace are obliged to pass. After firing the retorts, the first thing to come over is what we call 'light oil', though the man who made your kerosene would not call it so. This is from 35° to 40° Baumé, or 0.850 to 0.830 specific gravity, and we cut this off to return to the kerosene manufacturers. The balance of the charge begins now to fall rapidly in gravity (Baumé), and continues falling or getting heavier till the end of distillation, at which time the 'stuff' begins its exit and drops lazily into the trough. At this time the bottom of the still is red-hot, and has on it as residue from the charge a covering of coke from 8 to 10 inches thick. This coke is very porous and spongy, and very light, but is good for fuel, and makes little or no smoke." Farther on, in reference to the same thing, Mr. Truax says: "After several hours the stream, after having reached its maximum, begins to darken in color, and soon ceases altogether. Then your 'stuff' drags its slow length along. At this time everything is furiously hot; the bottom red-hot; the fire-brick of the furnace glowing like fire itself, and luminous as the fire, and the little oil remaining with the coke has a heat so great as to make its elements interchange in such a way as to make a large quantity of carbon unite with the very small quantity of hydrogen that is left behind the general exit so as to form your stuff. Several times in my experience, owing to some accidents, we have had to draw the fires before your stuff came over, and on opening the still or retort we found regular pitch, resembling in nearly every way pine-pitch or coal-tar (for roofing) pitch, except in absence of odor and taste, and in not being quite so plastic, but nevertheless a true pitch. Now the distillation of this pitch makes your stuff, that is, under favorable conditions."

I agree with Mr. Truax in his theory here expressed, that the thallene does not exist ready formed in the petroleum, or even in the petroleum tar, but is, like anthracene for example, a product of destructive distillation at something like a red heat. (a)

In a previous paper Professor Morton thus describes the preparation of thallene:

The crude tarry matter is well washed with benzine (petroleum naphtha), then with alcohol, and is lastly dissolved in benzole (coal-tar naphtha), filtered hot, and crystallized out on cooling. It is then obtained as a mass of very minute, needle-like crystals of a greenish-yellow color and pearly luster in the mass. * * * This I described under the name of Viridin in a paper read before the American Institute in New York, and drew attention to the very remarkable spectrum which its fluorescent light yielded, which resembled in a striking manner that of anthracene, while the crystalline form, solubilities, and fusing points of the two bodies were decidedly unlike. (b)

Hemillian also obtained petrocene in 1877 (J. C. S., xxxii, 867).

In 1879 MM. L. Preunier and R. David published a paper "Upon the nature of certain accessory products obtained in the industrial treatment of Pennsylvania petroleum", (c) which was followed and continued in another paper by M. Preunier, entitled "Study upon the unsaturated carbides derived from American petroleum". (d) In 1876 Dr. H. W. C. Tweddle exhibited at Philadelphia a greenish substance that he called "petrocene", from which he obtained a yellowish-green substance which he called "thallene". This was the raw material of this research, the few kilograms which were exhibited being obtained from 50,000 barrels of petroleum. The density of petrocene, that is to say, the crude material, is about 1.206. It was separated into lighter paraffines having a density of about 0.990, and heavier hydrocarbons of about 1.27, bromine and sulphuric acid separated from 5 to 15 per cent. of paraffine having a very high melting point, 70°, 80°, and 85° C., ordinary paraffine melting at 65° C. The unsaturated hydrocarbons, anthracene, phenanthrene, chrysene, chrysozene, and pyrene were recognized. Organic analysis showed a hydrocarbon containing from 88 to 96 per cent. of carbon, which is a larger percentage than is found in coal, even anthracite rarely attaining 95 per cent.

The following year (1880) MM. Preunier and Eug. Varenne published another paper "Upon the products contained in the cokes of petroleum". (e) They obtained a compound giving on analysis a mean of 97.9 per cent. of carbon, which corresponds to the theoretical compound $(C_{18}H_2)_n$, requiring 97.95 per cent. of carbon. These results, say the authors, conform perfectly to the general views of M. Berthelot, and confirm their own previous researches.

In 1873 MM. Le Bel and A. Muntz examined the black coloring matter of the semi-liquid asphalt of Pechelbronn (Bas. Rhin). (f) It is obtained in brittle, black scales from solution in carbon disulphide, and its coloring

a Am. Chem., vii, 88.

b Ibid., iii, 162, 106.

c B. S. C. P., xxxi, 158; B. D. C. G. B., 1879, 366.

d Ibid., xxxi, 293; Ibid., 1879, 843.

e Ibid., xxxiii, 545, 567; Ibid., 1880, 1141.

f B. S. C. P., xvii, 156.

power compares with aniline. They gave it the name "asphaltine", first given by Boussingault to a similar substance, and compare the analysis of this compound with that of a China bitumen as follows:

Carbon	Pechelbronn.	China.
Hydrogen	86.2	86.8
	8.8	8.7

As it is not volatile, the authors conclude that the asphalt is not a product of distillation.

In 1874 MM. Hell and Mendinger examined the organic acids of crude petroleum, (a) but the examination was not conducted in such a manner as to determine whether the acids obtained were an educt or a product of petroleum. They agitated the second running (specific gravity 0.857) of heavy Wallachian petroleum with caustic soda, and treated the flocculent precipitate with sulphuric acid. The result was a mixture of oily acids very difficult to separate, as they were decomposed by distillation. They finally succeeded in separating a colorless fluid, feebly acid, that produced a flocculent body with sodium or potassium, resembling soft soap, and they believed it belonged to a new series of fatty acids.

While these researches have been undertaken abroad, in this country Professor Samuel P. Sadtler, of the University of Pennsylvania, has been conducting a series of experiments upon petroleum and associated substances, with results that are embraced in the following extract from a letter dated Philadelphia, November 4, 1881, addressed to myself:

Classifying the subject under the three heads of: 1, Gaseous products accompanying crude petroleum; 2, Crude petroleum; and, 3, Solid products accompanying and derived from the petroleum, I started with the first. I made analyses of some ten lots of "natural gas" taken from wells in different parts of the oil-field, and representing different geological horizons as far as possible. As there was some doubt as to whether the results of eudiometric analysis could indicate the presence of the higher members of the paraffine series, I supplemented these analyses by a series of absorption tests made on the spot. Thus I passed a current of natural gas for a time through absolute alcohol, which, while it does not dissolve hydrogen, absorbs marsh-gas slightly, ethane, propane, and the higher hydrocarbons in increasing amount. The hermetically-sealed flasks of the alcohol were then examined in my laboratory, and the gases absorbed driven out by heat and collected over mercury and analyzed. They proved to be chiefly ethane and propane. I also passed a current of the gas through bromine, both pure and alcoholic, so as to absorb the olefines. On after examination in my laboratory, by neutralizing the free bromine with soda and diluting, I succeeded in separating out colorless oily drops of ethene dibromide, and presumably, though not certainly, propene dibromide. These results were read in part before the American Philosophical Society, and were reported in its proceedings. (b)

In the study of the liquid crude oils, after classifying the oils from the different geological horizons (with information supplied to me by Mr. John F. Carrl), and noting gravities, color, and other physical properties, I proceeded to classify them by filtration (as far as possible in the cold) with animal charcoal and with mineral materials, like clay, alumina, etc. I did this with a view of examining chemically and microscopically the coloring impurities thus withdrawn. My results with these portions withdrawn by filtration are very incomplete; still I think they are largely made up of the members of the higher and more condensed hydrocarbon series, like anthracene, etc., and not simply amorphous carbon, as supposed by some chemists. In corroboration of this view I may say that in the crude oils picric acid will strike a deep blood-red color, like the color of its compound with anthracene, fluorine, etc., whereas in the yellow oil clarified in the cold by animal charcoal no such result is gotten. I also verified with a number of crude oils Schorlemmer's observation that olefines are present, capable of being withdrawn by bromine, and in small quantities members of the benzole series, capable of yielding nitro-derivatives like nitro-benzole and nitro-toluole. Indeed, taking several distinct fractions, gotten from Bradford oil, I got notable quantities, in the lightest fraction light-yellow nitro-benzole, and in the higher fractions reddish-yellow nitro-toluole and probably higher products. I also extracted paraffine from a number of the crude oils by mixing several volumes of ether with the oil and then chilling, when almost all the dissolved paraffine will separate and can be filtered off.

I commenced a study of the spent acid from a refinery in Titusville that had been running for several weeks exclusively on green oil from Petroleum Centre, hoping to get a class of sulpho-conjugated oils from it for study. I did not get further, however, than to separate them from the free sulphuric and sulphurous acids, and so have them yet.

Lastly, of the solid products which accompany petroleum I examined the paraffine of buttery or firmer consistence which separates out on the tubing or derrick-frames in Bradford oil-wells. This was dark in color, looking like the crude ozokerite of Galicia, but not so firm. It had all the characters of a paraffine mixture. I had also collected a whitish buttery mass from several flowing wells near Warren, Pennsylvania. This, on examination, proved to be a very perfect emulsion of oil and water, one which would stand for months, but separated into distinct layers of oil and water when warmed. I also took up for examination the solids gotten from Pennsylvania petroleum by pyrogenic formation. Of this character were petrocene and allied products first mentioned by Dr. Herbert Tweddle, and from which Professor Henry Morton extracted thallium. I had worked with it some months when Preunier published an account in the *Ann. de Chim. et Phys.* of an examination of the same substance. I then published in Remsen's *American Chemical Journal* an account of my results, showing the presence of several new hydrocarbons. (c)

In an article published by Professor Sadtler in 1876, he well shows the unsatisfactory condition in which the chemistry of petroleum stands at present. (d) After speaking of the various researches had up to that date, he says:

What was the material used for these investigations? Were the crude petroleum examined by these different authorities exactly the same, or if by chance they might have been, are they to be compared with all other petroleum now known? Those familiar with the crude oils as produced in the different sections of Venango, Clarion, and Butler counties, and very recently in Warren and McKean counties also, will know that these oils vary in color from a light amber to a dark black, and in gravity from 30° to 55° Baumé—from thick lubricating oils to nearly pure benzene. Moreover, they come from very different strata, or "sand rocks", as they are termed. * * *

It will thus be seen that if we wish to study the chemical composition of petroleum thoroughly we have a considerable body of material to choose from. This material must be carefully assorted, too, before any satisfactory study of the petroleum can be made. The great bulk of the crude petroleum that is sent to the refineries or is exported is shipped by the pipe-line companies, who have their network of pipes ramifying through whole districts, collecting the entire yield of a district and storing it in their immense tanks. To study such crude petroleum would be like analyzing the sweepings of a mineral cabinet.

a B. D. C. G. B., vii, 1216.

b P. Am. P. S., xviii, 44.

c Am. Chem. Jour., i, 30.

d Am. Chem., vii, 181.

With perhaps a few exceptions, these remarks apply as forcibly to the work that has been done upon all other petroleum as to those of Pennsylvania.

The various attempts to produce by synthetic processes the oils that constitute petroleum will be noticed in detail when treating the chemical theories regarding its origin. They may be briefly stated as follows: Commencing in 1876 with Berthelot's synthesis of these liquids through the reaction of alkali metals, calcium, carbonate, and steam, we next have, in 1871, Byasson's successful experiments with steam, carbonic acid, and iron at a white heat; then, in 1877, Friedel and Craft's synthesis through the action of chloride of aluminum; then the same and the following year the reaction produced by M. Cléoz upon carbides of iron and manganese by diluted sulphuric acid and boiling water; and finally, in 1878, Landolph's complex synthesis through the action of fluoroborates. (a) M. Adolph Wurtz has shown that hydride of amyl (found in petroleum) and other hydrocarbons can be produced by the action of zinc ethyl on iodide of allyl. (b)

These oils have also been produced by the destructive distillation of the animal fats through the use of superheated steam. Warren and Storer fractionated the distillate from a lime soap of menhaden oil and obtained the members of the paraffine series, the homologues of olefiant gas, and the benzole group. (c) Cahours and Demarcay fractionated an oil boiling below 100° C., obtained by distilling fats by superheated steam, and found it contained pentane, hexane, and heptane. Another oil having a higher boiling point contained heptane, octane, nonane, decane, undecane, and a small quantity of dodecane, and probably cetane (hexdecane), all members of the paraffine series. (d)

SECTION 3.—THE CHEMICAL ACTION OF REAGENTS UPON PETROLEUM AND ITS PRODUCTS.

In attempting to classify the work that properly falls into this section I find it in a very fragmentary condition. The residues from gas works where petroleum is used have been studied by S. Cabot, jr., and he found them to contain the benzole compounds, but neither phenol nor cresol. (e) A. Leutz notices that the residues from gas, whether it is made from wood, coal, or petroleum, are identical, viz: aromatic hydrocarbons and phenols, naphthaline, anthracene, and phenanthrene, all of which are likewise obtained by passing petroleum through red-hot tubes filled with charcoal. Leutz experimented with Russian petroleum. (f) J. Tuttschew passed the vapor of an American naphtha through a red-hot tube filled with pumice and obtained gas and tar. One gram of the naphtha yielded a liter of gas having the following composition: (g)

	Per cent.
Acetylene	1.77
Ethyl and homologues	20.51
Marsh-gas and hydrogen	77.72

The effects of oxidation upon petroleum and its compounds have been quite widely studied. I succeeded in converting California petroleum into asphalts, which were lustrous black and brittle, soluble in carbon disulphide and fusible at 212° F.; but I have never examined either the asphalt or the gaseous products of the decomposition. (h) Walter P. Jenney has very carefully studied the effects of oxidation upon heavy petroleum distillates. He placed these distillates in a metallic still and aspirated a current of air through the oil continuously for from four to six days, maintaining the oil at the same time at a temperature of from 140° to 155° C, and as a result the volume of oil was greatly reduced, not by oxidation into water, but by cracking into lighter oils and gases and the conversion of a portion of the oil into oxidized residues, soluble in chloroform, but not in petroleum naphtha. He says:

These four substances, formed from one sample of oil, bear a peculiar relation to each other. The resin D, which is in solution in the hot oil, has the composition expressed by the formula $C_{46}H_{46}O_6$. Becoming oxidized, it precipitates as the brown powder $C_{40}H_{40}O_6$, and, settling on the bottom of the still, becomes heated to a higher temperature, changing into the solid asphalt $C_{40}H_{38}O_6$, or by a longer action of air $C_{40}H_{38}O_7$. (i)

These interesting and suggestive experiments bear an important relation to the technology of petroleum.

Hell and Mendinger oxidized the acid that they obtained from crude Wallachian petroleum by the action of nitric and chromic acids, and obtained acetic acid and a new acid having the formula $C_9H_{16}O_2$. (j) Berthelot has shown that the action of chromic acid on ethylene and its homologues at a temperature of 120° produces aldehyde and its homologues. (k) In 1870 E. Willigk treated paraffine at a high temperature with nitric and sulphuric acids, and obtained products that belonged to the series of the fatty acids. (l) In 1873, M. Champion subjected paraffine for sixty hours to the action of nitro-sulphuric acid, hyponitric acid vapors were given off, and an oil having been formed with an acid reaction, combining readily with alkalis, of which the formula is $C_{26}H_{26}NO_{10}$, he proposed for it the name paraffinic acid. (m) In 1874 M. A. G. Pouchet published a paper in relation to the action of nitric acid upon

a For references see page 60 et seq.

b *C. Rendus*, liv, 387.

c *M. Am. Acad.*, N. S., ix, 177; *A. J. S.* (2), xliii, 250.

d *Jour. Pharm. Chem.* (4), xxii, 241.

e *C. N.*, xxxvi, 140.

f *Rus. Chem. Soc.*, June, 1877.

g *J. f. P. C.*, xciii, 394.

h *P. Am. P. S.*, x, 460; *Geo. Surv. of California: Geology*, Appendix II, 86.

i *Am. Chem.*, v, 359.

j *B. S. C. P.*, 1877-82, 385; *B. D. C. G. B.*, x, 451.

k *J. C. S.*, xxxvi, 907.

l *B. D. C. G. B.*, 1870, 138.

m *J. de Pharm. et de Chimie*, Aug., 1872.

paraffine and the divers products that result from it. (a) He obtained in solution the fatty acids, chiefly caproic, but also butyric, caprylic and capric, and paraffinic acid insoluble. He regards paraffinic acid as having the formula $C_{48}H_{97}O_3$, HO, and paraffine as a definite compound with the formula $C_{48}H_{50}$, and not a mixture of different carbides of hydrogen, a conclusion that does not follow, unless he has shown that paraffines from all sources have the same composition and produce the same paraffinic acid.

In 1868 M. Grotowski, of Halle on the Saale, studying the effects of sunlight on illuminating oil, (b) exposed various kinds of oils in glass flasks to the rays of the sun for a period of three months, and found that they invariably absorbed oxygen and converted it into ozone. The air was ozonized even in well-corked vessels, the effect being, however, in some degree dependent upon the color of the glass. The respective results of these experiments were noted after a lapse of three months. American kerosene from petroleum, which had been exposed to the light in white uncovered glass balloons, had become so strongly ozonized that it scarcely burned, and the original bluish-white oil had assumed a vivid yellow color, the specific gravity being found to have increased 0.005; but American kerosene which had been kept in the dark for three months did not show any ozone at all, and burned satisfactorily. The oils were exposed from April to July, 1868. Those oils which had become strongly ozonized had also suffered a distinct change in odor, and the corks were bleached as if attacked by chlorine, while the others had remained unchanged in these particulars. These results are fully confirmed by the experience of the consumers and dealers in these oils, who all avoid obtaining "old oil", as it is called. It appears that redistillation with quicklime and clean iron nails restores the oils to their original state and properties. It is well known that the best illuminating oils, when allowed to stand for a long time in unused glass lamps, become yellow in color, less mobile, and of greatly impaired quality.

Dr. Stevenson Macadam, having investigated the action of petroleum on metals, concludes that it exerts a solvent action upon lead, zinc, tin, copper, magnesium, and sodium. (c) Engler refers to these experiments, and maintains that these metals are attacked by petroleum only under the influence of air or oxygen, when acid compounds are formed. Petroleum washed in caustic alkalies and distilled in carbonic acid has no solvent action on metals. (d)

CHAPTER V.—THE ORIGIN OF BITUMENS.

SECTION 1.—INTRODUCTION.

The origin of bitumens has been a fruitful subject of speculation among scientific men during the last half century. These speculations have been pursued along several quite different lines of investigation, and have been influenced by several different classes of experience. Generally speaking, they fall into three different categories, embracing those who regard bitumen as a distillate produced by natural causes, those who regard bitumen as indigenous to the rocks in which it is found, and those who regard bitumen as a product of chemical action, the latter class being subdivided into those who regard bitumen as a product of chemical change in natural products, of which carbon and hydrogen are constituents, and those who advocate a purely chemical reaction between purely mineral or inorganic materials. I propose to examine these theories in the inverse order in which they have just been stated.

SECTION 2.—CHEMICAL THEORIES.

The argument for a purely chemical origin of petroleum was first brought to the serious attention of scientific men through the publication of a somewhat noted paper by the distinguished French chemist Berthelot in 1866, whose conclusions are stated as follows:

If, in accordance with an hypothesis recently announced by M. Daubré, it be admitted that the terrestrial mass contains free alkali metals in its interior, this hypothesis alone, together with experiments that I have lately published, furnishes almost of necessity a method of explaining the formation of carbides of hydrogen. According to my experiments, when carbonic acid, which everywhere infiltrates the terrestrial crust, comes in contact with the alkali metals at a high temperature, acetylides are formed. These same acetylides also result from contact of the earthy carbonates with the alkali metals even below a dull-red heat.

Now the alkaline acetylides thus produced could be subjected to the action of vapor of water; free acetylene would result if the products were removed immediately from the influence of heat and of hydrogen (produced at the same time by the reaction of water upon the free metals) and the other bodies which are found present. But in consequence of the different conditions the acetylene would not exist, as has been proved by my recent experiments.

a *C. Rendus*, lxxix, 320; Dingler, cxxiv, 130; C. N., xxx, 154.
b *N. Jahrbuch f. Pharm.*, xxxvii, 187; Chem. C. Bl., 1872, 588.

c T. P. S. E. (3), viii, 463; J. C. S., xxxiv, 355.
d B. D. C. G. B., 1879, 2186; C. N., xli, 284.

In its place we obtain either the products of its condensation, which approach the bitumens and tars, or the products of the reaction of hydrogen upon those bodies already condensed; that is to say, more hydrogenated carbides. For example, hydrogen reacting upon the acetylene, engenders ethylene and hydride of ethylene. A new reaction of the hydrogen either upon the polymeres of acetylene or upon those of ethylene would engender formenic carbides, the same as those which constitute American petroleum. An almost unlimited diversity in the reaction is here possible, according to the temperature and the bodies present.

We can thus imagine the production by a purely mineral method of all the natural carbides. The intervention of heat, of water, and the alkali metals, together with the tendency of the carbides to unite with each other to form matters more condensed, are sufficient to account for the formation of these curious compounds. Their formation could thus be effected in a continuous manner, because the reactions which give birth to them are continually renewed. This hypothesis is susceptible of further development, but I prefer to dwell within the limits authorized by my experiments without wishing to announce other than geological possibilities. (a)

Continuing the same line of experimentation and argument, in 1869 M. Berthelot thus concludes another article:

In the preceding experiments wood, charcoal, and coal are changed into petroleum. * * * If one accepts either origin for petroleum that I have just mentioned, he is led to conceive the possibility of an indefinite formation of these carbides, whether they be relegated to an organic origin, and in consequence to the enormous mass of *débris* buried at an inaccessible depth, or whether they be relegated to a purely mineral origin, and in consequence to the incessant removal of the generative reactions. (b)

He further applies this hypothesis to the origin of the carbonaceous matter in the meteorite of Orgueil and other meteorites. (c)

In 1871 M. H. Byasson read a paper before the French Academy, which he concludes as follows:

The question of the origin of petroleum has already produced four or five different theories. In a research that certain considerations have led us to undertake, we have, by causing carbonic acid and water to react under very simple conditions, obtained a small quantity of an inflammable liquid nearly indifferent to sulphuric acid, and with an odor analogous to that of the carbides of petroleum. * * * The substances that we cause to react upon each other being widely distributed upon the globe, it will perhaps be possible to formulate a new theory of the formation of petroleum, to correlate it with the elevation of mountains and volcanic eruptions, and to group together several important facts prominent in the history of the earth. (d)

M. Byasson causes steam, carbonic acid, and iron at a white heat to react upon each other, and provides the requisite conditions in nature by assuming that sea-water penetrates the terrestrial crust and comes in contact with metallic iron at a white heat and at great depths beneath the surface.

In 1877 Messrs. Friedel and Crafts produced the hydrocarbides and acetones by a complex reaction, in which chloride of aluminum performed the essential part. (e)

On the 25th of February, 1877, M. Mendeljeff read a paper on the origin of petroleum before the Chemical Society of Saint Petersburg, which has been very widely noticed. I give below a translation of a *résumé* which appeared in the correspondence of the Chemical Society of Paris, and which is printed in its bulletin:

The appearance of springs of petroleum at the surface of the earth shows the tendency of those mineral oils to traverse by infiltration the different strata of the earth in reaching the surface, a natural consequence of their lower density as compared with water. The place where petroleum originates ought then to be situated beneath the strata where the springs themselves are found. The beds furnishing the mineral oil belong in general to several very different formations of the earth's strata. Thus in the Caucasus the petroliferous zone is formed in the Tertiary; in Pennsylvania, in the Devonian, and even Silurian. The place of the formation of the petroleum ought then to be sought in older strata. The sandstones impregnated with petroleum have never exhibited the carbonized remains of organisms. In general, petroleum and carbon are never found simultaneously; but it is difficult to suppose that petroleum resulted from the decomposition of animal and vegetable organisms, because it would be then impossible to represent the origin of petroleum without a corresponding formation of carbon. On the other side, it is impossible to imagine the existence of great quantities of organisms in the epoch preceding the Silurian and Devonian. These reflections have led the author to the supposition that petroleum is in no place of organic origin. In speaking of the hypothesis of La Place upon the origin of the earth, in applying Dalton's law to the gaseous state in which all the elements constituting the terrestrial globe ought to be found, and taking into consideration their relative densities, M. Mendeljeff recognizes the necessity of admitting a condensation of metals at the center of the earth. Among these it is natural to presume iron would predominate, because it is found in great abundance in the sun in meteorites and basalts. Admitting further the existence of metallic carbides, it is easy to find an explanation not only for the origin of petroleum, but also for the manner of its appearance in the places where the terrestrial strata, at the time of their elevation into mountain chains, ought to be filled with crevices to their center. These crevices have admitted water to the metallic carbides. The action of water upon the metallic carbides at an elevated temperature and under a high pressure has generated metallic oxides and saturated hydrocarbons, which, being transported by aqueous vapor, have reached those strata where they would easily condense and impregnate beds of sandstone, which have the property of imbibing great quantities of mineral oil.

This explanation of the origin of petroleum finds support from the following facts: The predominance at the surface of the earth of elements having a small atomic weight; the appearance of petroleum in directions corresponding to great circles; the relation remarked by several naturalists, particularly by M. Abich, between petroleum and volcanic manifestations.

In order to make this question clear, it is indispensable to study the different transformations of petroleum, its decomposition into marsh-gas and non-saturated hydrocarbons; of determining the chemical nature of mineral oils of different origin; also that of the saline water that ordinarily accompanies petroleum. Researches of this kind, in connection with profound geological studies, can alone render justice to the hypothesis stated above. (f)

In 1877 Mr. Clœz succeeded in obtaining hydrocarbons resembling certain constituents of petroleum as a result of the action of dilute sulphuric acid on a carbide of iron and manganese (spiegeleisen). The next year, by

using a carbide richer in manganese, he succeeded in producing the reaction with boiling water and obtained the oils as before. In concluding his paper on the subject he regards his results as a sufficient basis for an hypothesis by which to account for the origin of petroleum. (a)

In 1878 M. Fr. Landolph succeeded in obtaining these oils by an exceedingly complex process, in which he used fluoborates, affirming that "it is the great energy (affinity) of boron for the elements of water that ought to provoke those classes of reaction and permit us to obtain synthetically a great number of carbides of hydrogen with great facility". (b)

These chemical theories are supported by great names, and are based on the most complete and elaborate researches; but they require the assumption of operations nowhere witnessed in nature or known to technology.

I quote here a passage which I wrote in 1867, soon after M. Berthelot's original article, above quoted, first appeared:

The theory of M. Berthelot appears to me to derive less support from observed facts than any which has been proposed. It was doubtless formed with reference to the petroleum of Pennsylvania, which are among the purest mineral hydrocarbons of any found in large quantities. The very small proportion of nitrogen existing in these oils might perhaps be accounted for as an accidental constituent of the limestone, or as being mechanically mingled with the watery vapor. Neither supposition is at all probable, since nitrogen possesses such slight affinities. It adds nothing to its support to admit that the alkali metals do exist in the interior of the earth in the free state. (c) The very great difference observed between the varieties of petroleum (d) cannot be explained upon any hypothesis that regards them as the results of the same process acting upon like materials; neither should it be expected that a process yielding an almost "unlimited diversity" of products, under slightly varying circumstances, would furnish a uniform result over a very wide area. Samples of Pennsylvania petroleum of the same density, when gathered from widely separated localities, furnish identical (e) results upon analysis; so, too, do California petroleum, though gathered from localities 50 miles apart; and yet the two varieties of oil are exceedingly unlike. "It is, moreover, altogether erroneous to attempt to explain the causes of geological facts by the aid of supposed analogies with the complex apparatus of physical cabinets, whose existence in nature could scarcely be conceived by the boldest and most unrestrained imagination." (f)

The most conspicuous advocate of the theory that petroleum is a product of chemical reaction, by which marsh-gas is converted into more condensed hydrocarbons, appearing as fluid, viscous, and solid bitumens, is M. Coquand, who has so fully written upon the occurrence of bitumen in Albania and Roumania. He found mud volcanoes associated with the occurrence of petroleum in Sicily, the Apennines, the peninsula of Taman, and the plains of Roumania, and concluded that mud volcanoes produced petroleum and other forms of bitumen by converting marsh-gas into more condensed hydrocarbons. The following passage gives a summary of his opinions:

If the Carpathians have shown me only mineral oils in the state of naphtha more or less charged with tarry matters, and sometimes, but rarely, glutinous bitumen, that is to say, in the first stage of its existence and transformation, Selenitza ought to show me the same phenomena brought to the extreme limit of exhaustion; that is to say, bitumen reduced to a solid substance, incapable of spontaneous decomposition and of engendering new derivative products. It is rational to conclude that the history of that substance consists of two distinct evolutions, of which the first has for the principal theater of its active life North America and the Carpatho-Caucasian region, and the second the coasts of the Black sea and lower Albania, and as occupying an intermediate position between the two extreme states, which represent birth and death, we will mention glutinous bitumen, an intermediate and unstable substance through which petroleum passes, having lost its primitive fluidity and acquired that consistence which ought always to preserve it, which might be called the period of old age and decrepitude. (g)

M. Grabowski, in an article on ozokerite, having advanced similar opinions with reference to marsh-gas, says:

Very little is known about its formation. It appears to me to be very probable that it has to be considered as a product of the oxidation and condensation of the petroleum hydrocarbons. * * * By this hypothesis the formation of petroleum may be reduced to an oxidation of marsh-gas, and thus the close connection between ozokerite, petroleum, and coal be explained in the most simple manner. (h)

No adequate representation of the reaction is given. C. H. Hitchcock has supported similar views. (i)

It may be said, in reference to this theory, that, in so far as it expresses the fact that maltha represents an intermediate stage in the transformation of petroleum into asphaltum and recognizes the chemical relation existing between marsh-gas and the petroleum compounds, it is entitled to consideration; but in the chemical processes of nature complex organic compounds pass to simpler forms, of which operation marsh-gas, like asphaltum, is a resultant, and never the crude material upon which decomposing forces act.

a C. R., lxxxv, 1003, lxxxvi, 1248; J. C. S., xxxiv, 481, 716.

b C. R., lxxxvi, 1267. Professor A. Wurtz has produced some of the constituent hydrocarbons of petroleum by the action of zinc ethyl on iodide of allyl, but with great forbearance he refrains from assuming that these reagents are found in the interior of the earth. C. R., liv, 387.

c This statement is equally true of spiegeleisen, etc.

d See Chapter IV.

e The word identical will not apply to the present condition of the Pennsylvania region as it did in 1867, but should be replaced by similar.

f P. A. P. S., x, 445. Quotation from Bischof: *Chemical and Physical Geology*; Cav. Soc. ed., i, 243.

g B. S. G. F., xxv, 35.

h Hübner's *Zeitschrift*, 1877, 83; *Am. Chem.*, vii, 123.

i *The Geo. Mag.*, iv, 34.

SECTION III.—THE THEORY THAT BITUMEN IS INDIGENOUS TO THE ROCKS IN WHICH IT IS FOUND.

The opinion that petroleum is indigenous to the rocks in which it occurs has been maintained with great vigor by Dr. T. S. Hunt and Professor J. P. Lesley, these gentlemen basing their views upon their observations in Canada, West Virginia, and Kentucky. Dr. Hunt, having found the fossiliferous limestones impregnated with petroleum, which is particularly abundant in the fossils themselves, therefore concludes:

The facts observed in this locality appear to show that the petroleum, or the substance which has given rise to it, was deposited in the beds in which it is now found at the formation of the rock. We may suppose in these oil-bearing beds an accumulation of organic matters, whose decomposition in the midst of a marine calcareous deposit has resulted in their complete transformation into petroleum, which has found a lodgment in the cavities of the shells and corals immediately near. Its absence from the unfilled cells of corals in the adjacent and interstratified beds forbids the idea of the introduction of the oil into these strata either by distillation or by infiltration. The same observations apply to the petroleum of the Trenton limestone, and if it shall hereafter be shown that the source of petroleum (as distinguished from asphalt) in other regions is to be found in marine fossiliferous limestones a step will have been made toward a knowledge of the chemical conditions necessary to its formation. (a)

In a paper published some years later the same gentleman says:

In opposition to the generally received view, which supposes the oil to originate from a slow destructive distillation of the black pyroschists belonging to the middle and upper divisions of the Devonian, I have maintained that it exists, ready formed, in the limestones below. All the oil-wells of Ontario have been sunk along denuded anticlinals, where, with the exception of the thin black band sometimes met with at the base of the Hamilton formation, these so-called bituminous shales are entirely wanting. The Hamilton formation, moreover, is more oleiferous, except in the case of the rare limestone beds, which are occasionally interstratified. Reservoirs of petroleum are met with both in the overlying quaternary gravels and in the fissures and cavities of the Hamilton shales, but in some cases the borings are carried entirely through these strata into the corniferous limestone before getting oil. A well was sunk at Oil Springs to a depth of 456 feet from the surface and 70 feet into the solid limestone beneath the Hamilton shales before meeting oil. (b)

He says further, in support of this opinion:

In this (the Trenton) we meet for the first time with petroleum, though in much less abundance than in the higher rocks. In the township of Pakenham, the large orthoceratites of the Trenton limestone sometimes hold several ounces of petroleum in their chambers, and it has been met with under similar conditions in Lancaster. It has also been observed to exude from the fossil corals of the Birdseye limestone at Rivière à la Rose (Montmorency). The limestones of this group, which are generally more or less bituminous to the smell, are peculiarly so in some parts of the county of Montmorency, and not only give off a strong odor when struck, but when burned for lime evolve an abundant bituminous vapor on the first application of heat. The lithological representative of the Trenton group next appears in the corniferous formation, composed, like the former, of pure limestones, with chert beds, silicified fossils, and petroleum.

* * * It is in the Lower Devonian limestone, or corniferous formation, that the greatest amount of petroleum occurs, although Mr. Hall observed that the dolomites of the Niagara formation in Monroe county, New York, frequently contain mineral pitch, which is sometimes so abundant as to flow from the rock when this is heated in a lime-kiln. Concretionary nodules holding petroleum have also been observed in the Marcellus and Genesee slates, while the higher Devonian sandstones in New York and Pennsylvania are often impregnated with petroleum, and from these and from still higher strata issue the oil-springs of those regions. It is probable, however, that the source of the oil in these superior strata is to be found in the corniferous limestone, from which the petroleum of western Canada is undoubtedly derived.

* * * In the township of Rainham, on lake Erie, the shells of *Pentamerus aratus* are sometimes found to have an inner cavity, lined with crystals of calcite and filled with petroleum. Coralline beds impregnated with petroleum are found at Wainfleet and in Walpole, in the latter instance immediately beneath a layer of chert; but I have more particularly examined them in the township of Bertie, which is on the Niagara river opposite Buffalo. Here in a quarry are seen massive beds, slightly inclined, composed of a solid, crystalline, encrinural limestone, which appears not only destitute of petroleum, but, from the water by which it is impregnated, to be impermeable to it. In some of the beds are large corals of the genus *Heliophyllum*, the pores of which are open but contain no oil. Two beds, however, one of 3 and one of 8 inches, which are interstratified with these, are in a great part made up of species of *Heliophyllum* and *Favosites*, the cells of which are full of petroleum. This is seen in freshly-broken masses to be absent from the solid limestone, which forms the matrix of the corals, and resembles in texture the associated beds. As the fractured surfaces of the oil-bearing beds become dry, the oil spreads over them, and thus gives rise to the appearance of a continuous band of dark oil-stained rock, limited above and below by the lighter limestone, from which, however, it is separated by no planes of bedding. The layer of 3 inches was seen to be twice interrupted in an exposure of a few feet, thus presenting lenticular beds of the oil-bearing rock. Beside the occasional specimens of *Heliophyllum* without oil disseminated in the massive limestone, a thin and continuous bed of *Favosites* is met with, which is white, porous, and free from oil, although beds above and below are filled with it. It was in the weathered outcrop of one of these that was obtained the specimen in the cells of which was found the infusible and insoluble product of the oxidation of petroleum. When the oil-bearing beds are exposed in working the rock the oil flows out and collects on the water of the quarry. The facts observed in this locality appear to show that the petroleum, or the substance that has given rise to it, was deposited in the bed in which it is now found at the formation of the rock.

In the easternmost part of North America, and at the extremity of the peninsula of Gaspé, petroleum is again met with issuing from sandstones which belong to the base of the Devonian series. Beds of thickened petroleum, like those of Enniskillen, are here met with. Near to cape Gaspé there is a remarkable dike of amygdaloidal trap, 10 or 12 yards in breadth, the cavities of which are often lined with chaledony or with crystals of calcite and quartz. Many of these cells are filled with petroleum, which in some cases has assumed the hardness of pitch. (c)

Petroleum occurs saturating a stratum 35 to 40 feet thick about midway in the Niagara formation at Chicago, Illinois, the rock being so filled with petroleum that blocks of it which have been used in buildings are discolored by the exudations, which, mingled with dust, form a tarry coating upon the exposed surfaces. Though thus discolored, when freed from the bitumen, this rock is a nearly white, crystalline dolomite. An illustration of the effect of this exudation was to be noticed in one of the largest churches in Chicago before the great fire.

Dr. Hunt estimated the amount of oil held in the Niagara limestone of Chicago, and found it to be 4.25 per cent., an amount rather beneath the average. He continues:

A layer of this oleiferous dolomite, 1 mile (5,280 feet) square and 1 foot thick, will contain 1,184,832 cubic feet of petroleum, equal to 8,850,069 gallons of 231 cubic inches, and to 221,247 barrels of 40 gallons each. Taking the minimum thickness of 35 feet assigned by Mr. Worthen to the oil-bearing rock at Chicago, we have in each square mile of it 7,743,745 barrels, or, in round numbers, 7,750,000 barrels of petroleum. * * * With such sources existing ready formed in the earth's crust, it seems to me, to say the least, unphilosophical to search elsewhere for the origin of petroleum, and to suppose it to be derived by some unexplained process from rocks which are destitute of the substance. (a)

In reply to a letter of inquiry, Professor James M. Safford thus writes regarding the occurrence of petroleum in the neighborhood of Nashville, Tennessee:

In the limestone rocks of Nashville, representing those of the Silurian basin of middle Tennessee, and of course Silurian (lower), geodes or geode cavities in certain horizons are quite common. They are mostly calcite geodes, or cavities lined with crystals of calcite. Sometimes there is nothing but the calcite crystals within; then we have a lining of calcite crystals with dolomite, gypsum, anhydrite, often cleavable, and occasionally fluorite within. I have seen all of these minerals in one. Imperfect quartz geodes lined with quartz crystals occasionally occur. Barite and celestite and baryto-celestite occur together, and sometimes fluorite occurs with these. In a certain horizon there are many geode cavities lined with calcite crystals and containing within beautiful crystals of celestite, white and beautifully blue. Cavities occur containing celestite which are not lined with calcite crystals, and it is not uncommon to meet with geode cavities in our limestones lined with calcite crystals and containing more or less petroleum. I have seen as much as half a pint or even more in them.

There appears to be little room to doubt that the petroleum in these geodes is indigenous to the Nashville limestone.

The Clinton limestones of Ohio, lying immediately above the Cincinnati group and over the whole northern border of the Cincinnati anticlinal, contains petroleum in small quantities, but nowhere sufficient in amount to be of economic value. (b)

In the description of the method of "the existence of the petroleum in the eastern coal-field of Kentucky" Professor J. P. Lesley says:

At Old Oil Springs, on the south fork of Paint creek, a black reservoir of tar-like oil here occupies the center of a sloping bog, and is kept always full from a spring at its upper limit, near the top of the slope and foot of the cliffs, about 20 feet above the level of the stream. Fig. 3 shows the conformation of the ground, *a* the spring, *b* the reservoir, *c* the bed of Paint creek, *d* conglomerate No. XII. (c)

A mile farther down the stream, but on the opposite or right bank, and apparently 35 or 40 feet above the water, on a steep slope close under the projecting cliffs, is a similar spring, which has not produced any extensive bog for want of a level receptacle, but has yielded "large quantities" of oil in past years, and from which petroleum continues to run slowly all of the time. Fig. 4 shows the contour of the ground and the overhanging cliffs at two places near the spring. Three miles farther down the stream, and within a mile or less of its junction with the north or Open fork at Lyon's well, the oil is to be seen coming from the edge of the coal and ore-shales, just under the cliffs, which here tower to an amazing height. Fig. 5 represents in a formal manner this section and a pile of conglomerate crag called the Crow's Nest, between 100 and 200 feet high. There are here, immediately underneath the lowest plate of conglomerate (20 feet thick), 5 feet of shales, then 2 feet of yellow sandstone, then 1½ to 3 inches of ball ore, then black and blue slates to the creek level. A mile or two up the creek there are in these black slates two distinct beds of coal, 6 feet apart, the upper 10 inches, the lower 24 inches thick; and oil flows from them continually in small quantities. At Davis, where the road crosses Paint creek, just below the mouth of Little Glade run, the conglomerate being here 230 feet thick and the streams flowing from the bottom of it between straight vertical walls, the black petroleum is perpetually welling out, not only from under the conglomerate, but from crevices in the bare faces of the rocks, accompanied, as elsewhere, by yellow peroxide of iron.

It is evident from the description given above—and the same description will answer for a large number of similar springs in the numerous gorges through which the Licking waters find their way westward into the Blue Grass country of middle Kentucky—that the petroleum of the oil-springs of Paint creek (*d*) has had its home in the great conglomerate at the base of the coal measures; still has, we may say, for it is still issuing in apparently undiminished quantities from the same. A conglomerate age or horizon of petroleum exists. This is the main point to be stated, and must be kept in view, apart from all other ages or horizons of oil, whether later or earlier in order of geological time. The rock itself is full of the remains of coal plants, from the decomposition of which the oil seems to have been made. I noticed in the great rock pavement at Lyon's well, over which the creek water flows, many sections of tree branches and stems mashed flat, each section being, say, 6 inches long by one-eighth of an inch wide in the middle, and when a jack-knife was thrust down into the slit, so as to clear it of mud, the black tarry oil would immediately exude and spread itself over the water. A pointed hammer spalling off flakes of the rock on each side showed not only that the slit itself was full of thick oil, but that the whole rock was soaked with it, except along certain belts (an inch or less wide and very irregular), which for some unexplained reason remained free from oil. Some of the great blocks of rock that have fallen from the cliff too recently to be as yet decomposed are literally full of the marks of the broken macerated driftwood of that period. For hundreds of square miles this vast stratum of ancient sea sand is a thick packed herbarium of coal-measure plants. If the loose sands of the bank of Paint creek, derived, as they are, from this sand-rock, can at the present day receive and retain vast quantities of petroleum in spite of the perpetual washings to which they are subjected, we can easily conceive of the wide, flat, sandy shores of the coal islands of the ancient archipelago of the coal era becoming completely charged with the decomposed and decomposable reliquiae of both the plants of the land and the animals of the sea. (e)

It is as yet beyond our ability to distinguish the several original sources of the petroleum obtained at different depths from any one well. The specific gravities of the oil, decreasing with the increase of depth, is a fact which shows conclusively that a chronic evaporation or distillation of the whole mass of oil in the crust of the earth (within reasonable reach of the surface) has always been, and is still, going on, converting the animal and plant remains into light oils, the light oils into heavy oils, the heavy oils into asphalt or albertite, the process being accompanied at every stage with the liberation of gas. Therefore the quantities of lubricating oil coming out from the

a A. J. S. (3), i, 420.

b Professor Edward Orton in a communication to S. F. Peckham.

c P. A. P. S., x, 39.

d Professor Lesley appears to regard the name "Paint creek", as suggested by the iridescent film of petroleum floating on the water.

e P. A. P. S., x, 39.

conglomerate along the valleys of Paint creek prove the existence of immense quantities back from the cliff in the rock itself under all the highlands. And for the same reason the heavy oils obtained first from Lyon's and Donnell's and Warner's wells, followed by lighter oils from a greater depth, prove the existence of yet uncalculated quantities of still lighter oils at still greater depths, and of a world of gas-pressure which ought to make its presence known whenever there have been rents in the crusts, down-throws, fallings-in, or serious sloping of the stratification; in a word, any sort of natural vent. (a)

The paper from which these extracts are taken was read before the American Philosophical Society, April 7, 1865. It expresses the opinion of which Professor Lesley has been one of the strongest advocates, that the petroleum of the Appalachian system is indigenous to the rocks in which it is found. It is to be inferred, however, that his views as related to the origin of the petroleum found in northwestern Pennsylvania have become somewhat modified, although in precisely what manner is not clear. In the introduction to Report III of the *Second Geological Survey of Pennsylvania*, p. xv, Professor Lesley says:

The origin of petroleum is still an unsolved problem. That it is in some way connected with the vastly abundant accumulations of Paleozoic sea-weeds, the marks of which are so infinitely numerous in the rocks, and with the infinitude of coralloid sea animals, the skeletons of which make up a large part of the limestone formations which lie several thousand feet beneath the Venango oil-sand group scarcely admits of dispute, but the exact process of its manufacture, of its transfer, and of its storage in the gravel beds is utterly unknown. That it ascended rather than descended into them seems indicated by the fact that the lowest sand holds oil, when those above do not, and that upper sands hold oil when they extend beyond or overhang the lower.

If I understand Professor Lesley, these later statements, as well as that quoted regarding the chronic distillation that has always been, and still is, going on, express his opinion respecting the changes that convert the original petroleum content of the rocks into the different varieties of petroleum now met with, rather than the origin of the petroleum itself.

Professor T. Rupert Jones examined the asphaltic sand or rock of Trinidad, and found that when it is boiled several times in spirits of turpentine "it loses its bitumen and resolves itself into loose orbitoides and nummulinae, with a few other foraminifera, and (when cleaned by acid) a small proportion of green-black sand and a very few rounded grains of quartz". (b)

In a paper on the "Geology of a part of Venezuela and Trinidad" Mr. G. P. Wall describes the occurrence of bitumen as follows:

The asphalt of Trinidad is almost invariably disseminated in the upper group of the "Newer Parian". (c) When *in situ* it is confined to particular strata, which were originally shales containing a certain proportion of vegetable debris. The organic matter has undergone a special mineralization, producing bituminous in place of ordinary anthraciferous substances. This operation is not attributable to heat, nor to the nature of distillation, but is due to chemical reaction at the ordinary temperature and under the normal conditions of the climate. The proofs that this is the true mode of generation of the asphalt repose not only on the partial manner in which it is distributed in the strata, but also on numerous specimens of the vegetable matter in process of transformation and with the organic structure more or less obliterated. After the removal by solution of the bituminous material, under the microscope a remarkable alteration and corrosion of the vegetable cells becomes apparent, which is not presented in any other form of the mineralization of wood. A peculiarity attending the formation of the asphalt results from the assumption of a plastic condition, to which property its frequent delivery at the surface is partly referable; where the latter is hollow or basin-shaped, the bitumen accumulates, forming deposits such as the well known Pitch lake. Sometimes the emission is in the form of a dense oily liquid, from which the volatile elements gradually evaporate, leaving a solid residue. Mineral pitch is also extensively diffused in the province of Maturin, on the main (the other districts of the llanos were not sufficiently examined to determine its existence, which, however, is generally affirmed), and in still larger quantities near the gulf of Maracaibo, on the northern shores of New Granada and in the valley of the Magdalena, where it probably is a product of the same Tertiary formation. (d)

In England petroleum has been observed in a peat bog, and the lower layers of the peat were compacted into a sort of bituminized mass, which has been described by E. W. Binney as follows:

The only remarkable feature connected with the upper bed of peat at Down Holland Moss is the western portion of it being covered up with a bed of sand, and being probably sometimes subject to an infiltration of sea-water. * * * These circumstances, added to the fact of petroleum being found most plentifully at the edge of the sand, lead to the conclusion that it is produced by the decomposition of the upper bed of peat under the sand.

The chemical process by which such singular effects have been produced is a subject more fitted for the consideration of the chemist than the geologist, but the author supposes that petroleum is the result of slow combustion in the peat, and has been produced by a process partly analogous to that which takes place in the distillation of wood in closed vessels, when, owing to a total absence of oxygen, the combination of hydrogen and carbon in the form of hydrocarbons is effected. (e)

Petroleum has also been observed dripping from shales overlying a highly bituminous coal; (f) also in limestone containing remains of crustacea. (g)

Concerning the origin of the petroleum of Shropshire, Arthur Aiken says:

The thirty-first and thirty-second strata are coarse-grained sandstone entirely penetrated by petroleum; are, both together, 15½ feet thick, and have a bed of sandy slate-clay about 4 feet thick interposed between them. These strata are interesting as furnishing the supply of petroleum that issues from the tar-spring at Coalport. By certain geologists this reservoir of petroleum has been supposed to be sublimed from beds of coal that lie below, an hypothesis not easily reconciled to present appearances, especially as it omits to explain how the

a P. A. P. S., x, 53.

b Q. J. G. S., xxii, 592.

c A South American Tertiary group.

d Q. J. G. S., xvi, 467.

e Proc. Manchester Lit. and Phil. Soc., iii, 136.

f T. G. S. L. (2), v, 438.

g Ibid. (1), ii, 199.

petroleum in the upper of these beds could have passed through the interposed bed of clay so entirely as to leave no trace behind. It is also worthy of remark that the nearest coal is only 6 inches thick, and is separated from the above beds by a mass 96 feet in thickness, consisting of sandstone and clay strata, without any mixture of petroleum. (a)

The observations of Wall in Trinidad appear to establish beyond a doubt that the bitumen of that locality has been and is being produced from a peculiar decomposition of woody fiber. Bright and Priestwich both regard the petroleum of England as indigenous in the limestones and shales, and the testimony of Binney is conclusive as to its production from the decomposition of peat on Down Holland Moss.

Professor A. Winchell says:

It seems to have become established from recent (1866) researches that the petroleum of the Northwest not only accumulates in several different formations, but also originates from materials stored up in rocks of different geological ages from the Utica slate to the coal conglomerate, and perhaps the coal measures. (b)

Professor J. D. Whitney has suggested that the infusoria, the remains of which are so abundant in certain sedimentary rocks, are the original source of the petroleum occurring in them, and says:

In conclusion, it may be remarked that the marine infusorial rocks of the Pacific coast, and especially of California, are of great extent and importance. They occur in the coast ranges from Clear lake to Los Angeles. They are of no little economical as well as scientific interest, since, as I conceive, the existence of bituminous materials in this state, in all their forms, from the most liquid to the most dense, is due to the presence of infusoria. (c)

SECTION 4.—THE THEORY THAT BITUMEN IS A DISTILLATE.

Humboldt, in 1804, observed a petroleum spring issuing from metamorphic rocks in the bay of Cumana, and remarked:

When it is recollected that farther eastward, near Cariaco, the hot and submarine waters are sufficiently abundant to change the temperature of the gulf at its surface, we cannot doubt that the petroleum is the effect of distillation at an immense depth, issuing from those primitive rocks beneath which lie the forces of all volcanic commotion. (d)

The researches of Reichenbach led him to suggest, in 1834, that "when we remember that coal is so filled with the remains of plants that its origin has been attributed entirely to the destroyed vegetables of an early period, it must appear probable that petroleum was formed from such plants as afford these oils, and, in one word, that our mineral oil is nothing but turpentine oil of the pines of former ages; not only the wood, but also the needle-like leaves, may have contributed to this process, which is not a combustion, but is, I believe, simply the result of the action of subterranean heat." (e)

French writers generally have expressed their conviction that bitumens have resulted from the action of heat on strata containing organic matter.

In 1835 M. Rozet read a paper before the Société Géologique de France, in which he discussed the occurrence of asphaltic limestone at Pymont. He represents it as a mass of limestone not stratified, but crossed with fissures in all directions, and contains 9 to 10 per cent. of bitumen and pure carbonate of lime. The limestone is accompanied by a molass or a sort of breccia, consisting of gravel of quartz and schistose rocks cemented with asphalt. The molass contains from 15 to 18 per cent. of asphalt, but the bitumen extracted from the limestone and molass is identical. He continues:

The bituminous matter is found equally in the calcareous rock and the molass that covers it. It is evident that the action that introduced it into the two rocks is posterior to the deposition of the latter. The manner in which it is distributed in great masses, which throw their ramifications in all directions, joined in such a manner that the superior portions contain generally less bitumen than the remainder of the mass, indicate that the bitumen has been sublimed from the depths of the globe. * * * The nature of the bituminous rocks (molass, cretaceous limestone, and calcareous schist) admit perfectly of this sort of action. The molass and the limestone are so porous that they easily absorb water and the calcareous schist sticks to the tongue. Thus these rocks could have been easily penetrated by the bituminous vapors, which probably penetrated all three of them at the same time.

The epoch of the introduction of the bitumen into the preceding rocks being necessarily posterior to the deposition of the molass, it may be presumed that it corresponds to that of the basaltic eruptions which many facts prove to have been often accompanied with bituminous material. * * *

It may be objected that such basaltic rock does not appear in all the extent of the Jura. To that I reply that they are found in the neighborhood, in Burgundy and in the Vosges; and further, that in the changes in the surface of the soil, whether occasioned by fractures or by the disengagement of vapors, the plutonic rocks do not necessarily appear at the surface. Perhaps in the deep valleys of the Jura the basalts are at a very slight depth. * * * In the Val de Travers, near Neufchatel, similar phenomena are observed. (f)

In 1846 Mr. S. W. Pratt described the occurrence of bitumen at Bastenee, a small village in the south of France, 15 miles north of Orthez. The surrounding country is formed of small conical hills 200 or 300 feet high, separated by a coarse sandy limestone belonging to the cretaceous system. The upper part consists of variously colored sands and clays from 50 to 60 feet thick, the whole covered by gravel and sand, which in all directions

a T. G. S. L. (1), i, 195.

b A. J. S. (2), xii, 176.

c *Bul. Acad. Sci. San Francisco*, iii, 324. Dr. J. S. Newberry has lately erroneously attributed this theory to S. F. Peckham, *Ann. N. Y. Acad. Sci.*, ii, No. 9.

d *Humboldt's Travels*, III, 114, Bohn's ed.

e *Schweigger Seidel's Jahrbuch*, ix, 133; *Ph. Jour.*, xvi, 376.

f B. S. G. F. (1), vii, 138.

extends for many miles. These sands and clays are usually horizontal, but are occasionally disturbed and highly inclined. This is occasioned by the protrusion of igneous matter, which is there found in connection with them. The bitumen is worked in three localities near each other, and occurs in beds from 5 to 15 feet thick, which vary much in character, the upper part consisting of looser and coarser sand, with a less proportion of the bitumen, while the lower part is more compact, containing finer sand, and being chiefly composed of bitumen. The sands and clays contain no fossils except occasional pieces of lignite and bitumen, and are generally free from extraneous matters, except in two localities, where numerous shells are found which may be referred to the Miocene period. In one of these localities, where the bitumen bed is from 10 to 12 feet thick, the shells are disposed in numerous layers a few inches apart, those of the same kind generally forming distinct layers, though sometimes, where the layer is thicker, many species are found together; and where the mass has been cut through vertically the appearance is very striking, bright, white lines appearing on a black bed of bitumen. The shells are neither broken nor disturbed, but are perfectly preserved, nor are the valves separated; but, owing to the loss of animal matter, on being exposed to the air they fall into powder. Perfect casts may be readily procured, as they easily separate from the sandy mass. The bitumen has evidently been forced into them when in a soft or liquid state, as the smallest cavities are filled, and this must have taken place after their deposition in the sands in which the animals lived. The date of this formation, as indicated by numerous species, may be referred to the Miocene era; and as the eruption of bitumen is evidently connected with the appearance of the ophite, an igneous rock which has produced such great changes in the Pyrenees, a limit may thus be obtained for these changes. (a)

In a notice upon the occurrence of asphalt in the environs of Alais, published in 1854, M. Parran makes the following statements:

Whatever be the origin of these substances, whether they be due to interior emanations from fissures of dislocation or to circumstances exterior and atmospheric, it is evident that there was during the Tertiary period an asphaltic epoch (*époque asphaltique*) in relation to which it is convenient to recall the numerous eruptions of trachytes and basalts which characterize that period and have probably acted by distillation upon the masses of combustibles hidden in the bosom of the earth.

He further remarks that asphalt occurs between Mons and Auzon, and continues:

The lacustrine formation, of which we have studied the bituminiferous part, is deposited in a vast depression of the secondary formation (*terrains*), represented here by the lower cretaceous and chloritic formations (*néocomienne et chloritiques*).

M. Parran concludes as follows:

Emanating by distillation from beds of combustible material inclosed in the inferior Cretaceous (*néocomienne*) formation or perhaps in the Carboniferous, if, as is probable, they extend to that place, the bitumen is raised in the midst of the fresh-water limestones (*calcaires d'eau douce*); there it is fixed by imbibition. Hot springs and sulphur springs abound in the vicinity. (b)

In 1868 M. Ch. Knar published an article on "The theory of the formation of asphalt in the Val de Travers, Switzerland". His conclusions are:

1. Asphalt (limestone impregnated with bitumen) is due to the decomposition in a deep sea of beds of mollusks, the decomposition taking place under a strong pressure and at a high temperature.

2. The free bitumen is formed also by the decomposition of certain mollusks or crustaceans in a sea of little depth, at a high temperature, but under an insufficient pressure to make this bitumen impregnate the oyster shells (*pour former ce bitume à imprégner les coquilles d'huître*).

3. Petroleum is due to the decomposition under water of mollusks, a decomposition which has taken place at a temperature too low to transform it into bitumen (asphalt), but under a pressure more or less considerable.

4. The beds of white limestone formed also by the accumulation of fossil oysters, and which contain neither asphalt nor petroleum, have been formed under such conditions that the products of the decomposition of animal organic matter have been evaporated.

5. Finally, combustibles only, or pyroschists (*bitumés fixes*), have been formed by the decomposition of plants, while all the preceding are of animal origin. (c)

In 1872 M. Thoré published a paper on the "Presence of petroleum in the water of Saint Boés (Basses-Pyrénées)", in which he says "petroleum floats on the water of the springs, and the rocks are saturated with it", and continues:

The comparison of observations seems to indicate in the department of the Basses-Pyrénées between the lower and middle Cretaceous formations a considerable impregnation of petroleum, due probably to igneous action or an eruption of ophite. The more this origin is examined the more one is convinced, because the greater part of the deposits of petroleum which prove valuable to the countries in which they are found are evidently related to the rocks of igneous origin, which may be considered as being the principal cause of its formation, or, at least, of the appearance of mineral oil. (d)

In 1837 M. Dufrenoy showed that the change from colored to white marble in the Pyrenees was due to the expulsion of bitumen by heat. (e) It is also maintained that jet is a distillate. (f)

a Q. J. G. S., ii, 80.

b *Ann. des Mines* (5), iv, 334. $(C_2SO_4)_2 + C_2 = (C_2CO_3)_2 + CO_2 + S_2$. The hydrogen of the bitumen also becomes oxidized and H_2S is formed.

c *Mon. Sci.*, 1865, 381.

d *L'Année Sci. et Ind.*, 1872, 251.

e B. S. G. F. (1), ix, 238.

f Simpson. San Francisco Min. and Sci. Press, 1874, 246.

One of the most noted papers on petroleum that has appeared in the United States was published by Dr. J. S. Newberry in 1859. In this paper he says:

The precise process by which petroleum is evolved from the carbonaceous matter contained in the rocks which furnish it is not yet fully known, because we cannot in ordinary circumstances inspect it. We may fairly infer, however, that it is a distillation, though generally performed at a low temperature.

We know that vegetable matter—and the same may be said of much animal tissue when the conservative influence of life has ceased to act—if exposed to the action of moist air, is completely disorganized by a process which we call decay, which is in fact combustion or oxidation. This change takes place slowly, and without evolution of light and heat, the usual accompaniments of combustion, in a degree appreciable by our senses.

When, however, carbonaceous organic tissue is buried in moist earth or submerged in water oxidation does not at once ensue, or at least takes place to a limited extent, measured by the amount of oxygen present. In these circumstances bituminization takes place. This process consists mainly in the union of hydrogen, from the tissue itself or its surroundings, with a portion of the carbon, to form carbureted hydrogen, which perhaps escapes, and the hydrocarbons constituting the bitumen, which usually remains as a black, pitch-like mass, investing the fixed carbon. By this process peat, lignite, and coal are formed, which are solids, and doubtless some liquid and gaseous hydrocarbons which escape. Now, when we heat these solid bitumens artificially at a sufficiently high temperature, if in contact with oxygen, combustion ensues, and water and carbonic acid are formed from them. At a lower temperature they are converted into gaseous hydrocarbons; still lower to oils. (a)

In an article published by Professor E. B. Andrews in 1861 he calls attention to the fact that the town of Newark, Ohio, has been for several years lighted by the uncondensed gas from the coal-oil manufactories, and infers that in the spontaneous distillation of bituminous substances a large amount of gas must be generated along with the oil. He refers to the theory which had been recently brought forward by Dr. Newberry, and says:

The chief objection to it is the fact that the coal, cannel and bituminous, in our oil regions gives no evidence of having lost any of its full and normal quantity of bitumen or hydrocarbons. For example, at Petroleum, Ritchie county, Virginia, where strata have been brought up by an uplift from several hundred feet below, seams of cannel and bituminous coal appear, which, if judged by the standard of Nova Scotia or English coals, have lost none of their bituminous properties. * * *

The other theory, that the oil was produced at the time of the original bituminization of the vegetable or animal matter, has many difficulties in its way. If the oil were formed with the bitumen of the coal, we should expect that wherever there is bituminous coal there would be corresponding quantities of oil. This is not so, in fact; for there is no oil, except in fissures in the rocks overlying the bituminous strata. * * * Again, upon this theory, it will be difficult to explain the large quantities of inflammable gas always accompanying the oil. If it is generated exclusively from the oil, then we should expect to find the quantity of the oil least where the gas-springs have for ages been most active, but at such places the oil, instead of being wasted, is most abundant. (b)

The distinguished French geologist, Daubrée, had published the previous year his *Studies upon Metamorphism*, in which he had discussed the relation of bituminous substances to metamorphism as follows:

Bitumens and other carbides of hydrogen, according as their state is solid, liquid, or gaseous, whether impregnating beds, flowing as petroleum, escaping from the soil, as in salses, mud volcanoes, burning springs, etc., are in general only the vent-holes (évents) of deposits of bitumens. The different deposits of bitumen present as general or at least remarkably frequent characteristics:

1. Association with saline formations.
2. Being situated in the neighborhood of deposits of combustible minerals, or strata charged with vegetable débris.
3. Being associated with igneous accidents, ancient or modern; that is to say, with volcanoes or irruptive rocks, or with dislocated strata.
4. Frequently accompanying thermal springs, often sulphurous, and deposits of sulphur. (c)

Several of my experiments account for these relations. In submitting fragments of wood to the action of superheated steam I have changed it into lignite, coal, or anthracite, according to the temperature, and I have also obtained liquid and volatile products resembling natural bitumens and possessing the characteristic odor of the petroleum of Pechelbronn. It is thus that the presence of bitumen in certain concretionary metalliferous veins is accounted for; as, e. g., Derbyshire, Camsdorf, and Raibl, in Carinthia.

Finally, bitumens are probably derived from vegetable substances; as it appears not to be a simple product of dry distillation, but to have been formed with the concurrent action of water, and perhaps under pressure, graphite being only the most exhausted (*épuisé*) product of these substances. These divers compounds of carbon are incident, then, to certain transformations which take place in the interior of the rocks, apparently under the influence of an elevated temperature. The activity and even the violence, at times capable of producing slight earthquakes, with which carbureted hydrogen has sometimes been associated in the Tauride, on the borders of the Caspian sea, and in the environs of Carthage, in South America, prove that the action that has sometimes disengaged bitumen continues to the present time. (d)

SECTION 5.—AN ATTEMPT TO INCLUDE OBSERVED FACTS IN A PROVISIONAL HYPOTHESIS.

The studies which I have made upon petroleum, extending now over a period of more than twenty years, and especially those which I have made in preparing this report, lead me to the conclusion that as yet very little is known regarding its chemical geology. As no one has studied the chemical properties of different varieties of petroleum in relation to their geological occurrence in any effective manner, it would be extremely rash for any one to dogmatize with reference to the origin of bitumens. I am, however, led to state the conclusions that a careful survey of our available knowledge of the subject has enabled me to reach. I am convinced that all bitumens have, in their present condition, originally been derived from animal or vegetable remains, but that the manner of their derivation has not been uniform. I should therefore exclude both classes of chemical theories; the first as

a Rock Oils of Ohio; *Ohio Ag. Rep.*, 1859.

b A. J. S. (2), xxxii, 85.

c I have omitted the numerous illustrations.

d *Études sur le Métamorphisme*, p. 73. M. Daubrée adds in a note: "Graphite and bitumen are associated in Java in proximity to volcanic formations and a Tertiary lignite, from which jets of carbureted hydrogen escape."

impossible, the second as unnecessary. There remains the hypothesis that bitumen is indigenous in the rock in which it is found and that which regards all bitumens as distillates, but whichever of these hypotheses be accepted the modifying fact remains that there are four kinds of bitumen:

1. Those bitumens that form asphaltum and do not contain paraffine.
2. Those bitumens that do not form asphaltum and contain paraffine.
3. Those bitumens that form asphaltum and contain paraffine.
4. Solid bitumens that were originally solid when cold or at ordinary temperatures.

The first class includes the bitumens of California and Texas, doubtless indigenous in the shales from which they issue. It is also probable that some of the bitumens of Asia belong to this class.

I have described the conditions under which bitumens occur on the Pacific coast of southern California in detail in the reports that I have made to the geological survey of that state, (a) the forms found there being a definite gradation, from fluid petroleum to solid asphaltum; but I have been unable to obtain any information from the parties who are operating in Santa Clara county other than that contained in newspaper reports, which are too unreliable to be used in this connection. In Ventura county the petroleum is primarily held in the shales, from which it issues as petroleum or maltha, according as the shales have been brought into contact with the atmosphere. The asphaltum is produced by further exposure after the bitumen has reached the surface. The shales are interstratified with sandstones of enormous thickness, but I nowhere observed the petroleum saturating them, although it sometimes escaped from crevices in the sandstone; nor was the bitumen held in crevices of any size nor under a high pressure of gas, as the disturbed and broken condition of the strata, folded at very angles, precluded such a possibility.

The relation of the asphaltum to the more fluid materials became a question of great importance to those engaged in prospecting for petroleum in that region in 1865 and later, and having made the solution of this problem a constant study for months, I finally came to the conclusion expressed above. My opinions were based on the following facts: a quantity of petroleum from the Cañada Laga spring remained in an open tank for fifteen months fully exposed to the elements, and increased 0.035 in specific gravity. Maltha has been obtained in wells so dense as to prevent their abandonment. Three attempts were made by the Philadelphia and California Petroleum Company to drill a well on the San Francisco ranch, and the greatest depth reached was 117 feet; but at that depth the maltha was so dense that it could not be pumped out, nor could it be drawn out with grappling-hooks, and was so tenacious as to clasp the tools so firmly as to prevent further operations. These wells were located near an asphalt bed on a steeply sloping hillside, where the strata were very much broken and easily penetrated by rain-water. The Pico series, yielding petroleum issuing from shales, overlaid with unbroken bands of thick sandstone, was only a short distance beyond in the same range of hills, and still further were several other localities, all yielding more or less maltha from natural springs, wells, and tunnels. The density of the bitumen, however, was in every case in proportion to the ease with which rain-water could percolate the strata from which it issued. On the plains north of Los Angeles an artesian boring that penetrated sandstones interstratified with shale yielded maltha at a depth of 460 feet.

Perhaps that portion of the sulphur mountain lying between the Hayward Petroleum Company's tunnel and Wheeler's cañon and the Big Spring plateau on the Ojai ranch furnishes the most striking illustration of the occurrence of bitumens in this region. A section of the strata at this point is given in Fig. 6. From this section it will be perceived that there is a synclinal fold in the shale forming the mountain, and that the strata dip inwards on both sides. The belt of rock yielding petroleum on the south side, in which the tunnels are driven, is fully protected by from 700 to 800 feet of shale, while the mountain side is nearly perpendicular. On the opposite side, however, the belt comes to the surface, presenting the upturned edges over a nearly horizontal area. The tunnels yielded the lightest petroleum at that time obtained in southern California, while the maltha in the Big Spring that issued from the detritus covering the shale was so dense in December, 1865, that it was gathered up and rolled into balls, like dough, and removed in that condition. (b)

The topography and stratigraphy of the coast ranges of Santa Barbara, Ventura, and Los Angeles counties is very complex. The Santa Barbara islands are volcanic, and lava-flows are described as having formed cascades over cliffs of sedimentary rocks as they descended into the sea. On the mainland no lava appears to have reached the surface, although between Las Posas and Simi, along the stage-road leading from San Buenaventura to Los Angeles, on an eroded plateau surrounded by low mountains, fragments of scoriæ are scattered over the ground. The coast ranges here appear to have been produced by parallel folds, each successively higher, by enormously thick beds of sandstone, interstratified with shale, were thrust up at an angle of about 70°, producing parallel anticlinals. These anticlinals were subsequently eroded in such a manner as in many instances to produce valleys and plateaus, where the sandstones are broken through to the softer shales beneath. This is the case at the western extremity of the fold which, commencing at point Concepcion, extends eastward to Mount Bernardino. West of the Sespé the sandstone crest has been completely removed and the shales cut away, until at the Rincon, east of Santa Barbara, the erosion reaches the sea-level, and beyond, to the westward, the upturned edges of the shale form the bed of the ocean. The narrow plain on which Santa Barbara stands, lying between

Santa Iñez mountains and the sea, consists of Pliocene and Quaternary sands and gravels resting upon the eroded shales. East of the Rincon and mount Hoar the table-lands lying in the trough of the anticlinal gradually ascend until at the Sespé the sandstone caps the high mountain to the eastward, said to be the highest in that region. This range extends eastward, occasionally broken by transverse cañons, until, near the headwaters of the Santa Clara river, at the Soledad pass, it becomes merged in the San Rafael range, beyond the San Fernando pass.

Between point Concepcion and point Rincon, where the stratum of sand occurs saturated with maltha, (a) the latter has risen and floated on the sea and attracted the notice of travelers ever since that coast was known to Europeans. At point Rincon, where the anticlinal recedes from the coast, maltha rises and saturates the Quaternary sands. As the ascending plateau passes farther inland, we find in the line of hills east of mount Hoar and in the Santa Iñez mountains a line of outcrop of the bituminous strata on the east and west sides of the basin. East of the San Buenaventura river the local synclinal fold in the shale forming the sulphur mountain gives four lines of bituminous outcrop, shown on the section, Fig. 6b. In the cañons east of the Sespé, wherever the bituminous strata have been reached by erosion, tar-springs and asphalt beds are the result. The deeply eroded narrow valleys which cover the country east of Santa Barbara and south of the coast range present in a distance of a few miles the greatest lithological variations, and expose the bituminous strata under the greatest possible diversity of conditions. For this reason we meet here every possible form of bitumen in every possible degree of admixture, with pure sand, soil, detritus, and animal and vegetable remains.

The exceedingly unstable character of these petroleum, considered in connection with the amount of nitrogen that they contain and the vast accumulation of animal remains in the strata from which they issue, together with the fact that the fresh oils soon become filled with the larvæ of insects to such an extent that pools of petroleum become pools of maggots, all lend support to the theory that the oils are of animal origin. (b)

The second class of petroleum includes those of New York, Pennsylvania, Ohio, and West Virginia. These oils are undoubtedly distillates, and of vegetable origin. The proof of this statement seems overwhelming. Pennsylvania petroleum was examined in 1865 by Warren and Storer (c) in this country, and in 1863 by Pelouze and Cahours in France, (d) who found the lighter portion to consist of a certain series of hydrocarbons, identical with those obtained in the destructive distillation of coal, bituminous shales, and wood when the operation was conducted at low temperatures. Messrs. Warren and Storer also discovered that the same series of hydrocarbons could be obtained by distilling a lime soap prepared from fish-oil. (e) The experience of technology has shown that if coals or pyroschists are distilled at the lowest possible temperature, particularly in the presence of steam, a black tarry distillate is obtained, along with a considerable quantity of marsh-gas and very volatile liquids, that cannot be condensed except at low temperatures. If these distillates are redistilled, the second distillate may be divided into several different materials, beginning with marsh-gas and ending with very dense oils, heavily charged with paraffine. It is impossible to conduct this primary or secondary distillation without producing marsh-gas, but the amount and the density of the fluid produced will depend on the temperature at which the distillation is carried on and the rapidity of the process. The use of superheated steam is found to increase the quantity of the distillate, and to prevent overheating and the formation of other hydrocarbons than those belonging to the paraffine series.

The section compiled by Mr. Carll shows the Devonian shales above the corniferous limestone and below the Bradford third oil-sand to be 1,600 feet in thickness. This shale outcrops along lake Erie, between Buffalo, New York, and Cleveland, Ohio. It is for the most part the surface rock in the neighborhood of Erie, Pennsylvania, and southward to Union City, and no one can examine it without noticing the immense quantity of fucoidal remains that it contains. Professor N. S. Shaler discusses in much detail the extent and character of the Devonian black shale of Kentucky, and estimates it to cover 18,000 square miles at an average depth of 100 feet, and to yield on distillation 15 per cent. of fluid distillate. It is not necessary to follow him in his calculations of the enormous bulk of this distillate as represented in barrels; the important point in this connection is that it is a very persistent formation, being revealed by borings over a very wide area, and doubtless extends beyond the boundaries of Kentucky, eastward beneath the coal measures which contain the petroleum. (f)

If, however, the Devonian black shales are inadequate, both on account of extent and position, as a source of supply, we may descend still lower in the geological series to the Nashville limestone and other Silurian rocks that underlie that region. Professor Safford, in a recent letter, writes:

The Lower Silurian limestone in the basin of middle Tennessee is about 1,000 feet thick. I have divided it in my *Geological Report* into the Lebanon limestone (or division) and the Nashville, each about 500 feet, the Nashville being the upper division. Including the Upper Silurian limestones, the whole thickness of the limestones, in which are found occasionally little pockets or geodes and cavities of petroleum, is not far from 1,200 feet.

Upper Silurian.....	Fect. 200
Lower Silurian (Trenton):	
Nashville limestones	500
Lebanon limestones.....	500

The most of the petroleum has been found in the upper part (the Nashville) of the Lower Silurian, as, for example, the larger cavities near or on the upper Cumberland river, in the neighborhood of the Kentucky line, both within Kentucky and Tennessee.

a See page 21.

b S. F. Peckham, P. A. P. S., x, 452.

c *Mem. Am. Acad. N. Si.*, ix, 176; A. J. S., (2), xli, 139.

d *Ann. C. et P.* (4), 1, 5.

e *Mem. A. A. N. S.*, ix, 177.

f *Rep. Geo. Survey, Kentucky*, N. S., iii, 109.

These limestones underlie the whole petroleum region of southeastern Kentucky and middle Tennessee.

The objection urged by Professor Andrews, that the coals in the measures of West Virginia and Ohio among which these oils occur have lost nothing of their volatile content, is without force here. Professor Shaler (*Report of the Geological Survey of Kentucky*, new series, iii, 171) says:

The condition of the beds that lie below the black shale in the Cincinnati group or in the Niagara section show that there has been no great invasion of heat since the beds were deposited. Clays, which change greatly under a heat of 1,000° F., are apparently exactly as they were left by the sea, and beds retain their marine salts just as when they were deposited. Any great access of temperature in this deposit of the Ohio shale would have been attended by an almost equal rise of temperature in the coal-beds which lie within a few hundred feet above; but these coal-beds are free from any evidences of distillation or other consequences of heat. We have already seen reasons for supposing an erosion of some 3,000 or 4,000 feet of strata from this section; if we could reimpose this section we should probably bring up the temperature of these rocks by the rise in the isothermals, or lines of equal internal heat, about 60°. * * * We are not able to suppose that the accumulation of strata would have elevated the temperature above the boiling point of water.

The hypothesis which may be found to account for the formation of this coal-oil must take into consideration the impossibility of its generation at another point and its removal to this set of beds and the impossibility of supposing that it has been in any way the result of high temperatures.

The range of temperature between "the boiling point of water" and "1,000° F.," which is here allowed, is ample for all purposes of explanation.

Mendeljeff objects that "the sandstones impregnated with petroleum have never exhibited the carbonized remains of organisms. In general, petroleum and carbon are never found simultaneously". These three objections—first, that the supply of organic matter is inadequate; second, that there are no evidences of the action of heat upon the rocks holding the oil; third, that there are no residues of fixed carbon observed in the rocks holding the oil—are those which have appeared to satisfy those who do not accept the hypothesis that regards petroleum as a distillate. I think the first has been already answered. The second and third I shall now examine.

It is not the effects of heat, as represented by volcanic action, that have produced petroleum, although in one notable instance paraffine and other constituents of petroleum have been found in the lava of Etna. (a) A comparison of the analyses of the gaseous emanations of volcanoes with those of gas and petroleum springs shows that the former consist mainly of carbonic acid and nitrogen, while the latter consist mainly of marsh-gas. Bitumens are not the product of the high temperatures and violent action of volcanoes, but of the slow and gentle changes at low temperature due to metamorphic action upon strata buried at immense depths.

The extent of the Paleozoic formations of the Mississippi valley and the general conformation of the bottom of the ancient seas has been fully described by Professor James Hall, who says: (b)

In all the Lower Silurian limestones we trace the outcrop to the west and northwest from the base of the Appalachians, in New York or in Canada, to the Mississippi river, and thence still in the same northwesterly direction. * * * Instead of finding the lower Helderberg (Upper Silurian) strata in lines parallel with those of the preceding rocks, the relative direction of the main accumulation and the principal line of exposures is diagonally across the others. * * * The line of outcrop and of accumulation has been from northeast to southwest, and they occur in great force far to the northeast in Gaspé, on the gulf of Saint Lawrence. * * * The greatest accumulation of material in the period of the Hamilton, Portage, and Chemung groups (Lower and Middle Devonian) lies in the direction of the Appalachian chain. * * * In Gaspé there are 7,000 feet of strata, * * * while in western New York the whole together would scarce exceed 3,000 feet. We have therefore the clearest evidence that the strata thin out in a westerly direction. * * * In considering the distribution of the masses of the formations which we have here described we find that the greatest accumulations have been along the direction of the Appalachian chain. The material thus transported would be distributed precisely as in an ocean traversed by a current like our present Gulf Stream; and in the gradual motion of the waters during that period to the west and southwest the finer material would be spread out in gradually diminished quantities, till finally the deposit from that source must cease altogether. * * * I have long since shown that * * * the portion of the Appalachians known as the Green Mountain range is composed of altered sediments of Silurian age. * * * The evidences in regard to the White mountains, to a great extent, are of newer age than those of the Green mountains, or Devonian and Carboniferous. * * * The statements of Sir William Logan in regard to the great accumulation of strata in the peninsula of Gaspé, together with the observations of Professor Rogers in the Appalachians of Pennsylvania, lead to the inevitable conclusion that the sediments of this age must everywhere contribute largely to the matter forming the metamorphic portion of the Appalachian chain, as well as to the non-metamorphic zone immediately on the west of it.

Reference to Map III shows the manner in which the outlined areas that have yielded petroleum correspond to the trend of these deposits of sediment as described by Professor Hall.

It is not necessary here to discuss the nature or origin of metamorphic action. It is sufficient for our purpose to know that from the Upper Silurian to the close of the Carboniferous periods the currents of the primeval ocean were transporting sediments from northeast to southwest, sorting them into gravel, sand, and clay, forming gravel bars and great sand-beds beneath the riffles and clay banks in still water, burying vast accumulations of sea weeds and sea animals far beneath the surface. The alteration, due to the combined action of heat, steam, and pressure, that involved the formations of the Appalachian system from point Gaspé, in Canada, to Lookout mountain, in Tennessee, involving the carboniferous and earlier strata, distorting and folding them, and converting the coal into anthracite and the clays into crystalline schists along their eastern border, could not have ceased to act westward along an arbitrary line, but must have gradually died out farther and farther from the surface.

a Silvestri, *Gaz. Chim. Ital.*, vii, 1; *Chem. News*, xxxv, 156; B. D., C. G., 1877, 293.
b *Nat. Hist. N. Y.*, Paleontology, iii, 45-60.

The great beds of shale and limestone containing fucoids, animal remains, and even indigenous petroleum, must have been invaded by this heat action to a greater or a less degree, and that "chronic evaporation" of Professor Lesley must have been the inevitable consequence.

Too little is known about petroleum at this time to enable any one to explain all the phenomena attending the occurrence of petroleum on any hypothesis; but it seems to me that the different varieties of petroleum, from Franklin dark oil, near the surface, to Bradford and Clarendon amber oil, far beneath the surface, are the products of fractional distillation, and one of the strongest proofs of this hypothesis is found in the large content of paraffine in the Bradford oil under the enormous pressure to which it is subjected. So, too, the great pools of oil in southern Kentucky are without doubt distilled from the geode cavities beneath and concentrated in superficial fissures of the rocks near the surface. The oil of the American well is very different in many respects from Pennsylvania oil; and that from the Phelps well, on Bear creek, Wayne county, Kentucky, has an odor identical with that of the petroleum of southern California, in that respect totally unlike the petroleum of West Virginia, and evidently an oil of animal origin that has not been subjected to destructive distillation.

If this hypothesis, which embraces all the facts that have thus far come within my knowledge, really represents the operations of nature, then we must seek the evidences of heat action at a depth far below the unaltered rocks in which the petroleum is now stored. We ought to expect to find the coal in its normal condition. We should not expect to find the carbonized remains of organisms in the rocks containing petroleum. As the metamorphic action took place subsequent to the carboniferous era, we should expect to find the porous sandstones of that formation in certain localities saturated with petroleum. We should expect a careful observer like General A. J. Warner to write concerning them:

Now, while these several sand rocks when they come to the surface contain calamites, stigmaria, and other fossil plants of the lower coal measures, they contain nothing from which petroleum could possibly have been derived. (a)

Moreover, we should expect to find these coal-measure sandstones and conglomerates on the western border of the heated area, where the thinning out of the deposits brought down the coal measures nearer the Devonian shales and Silurian limestones, first saturated with petroleum, and then, through ages of repose, gradually cut down by erosion into the cañons of Johnson county, Kentucky, and exhibiting all of the phenomena described by Professor Lesley.

The inadequacy of the scattered remains of plants in the coal-measure sandstones as a source of the petroleum that saturates them is shown by the following calculation:

Should the Mississippi send down one tree a minute for a century, with an average length of 40 feet and a foot in diameter, and these be laid together side by side at the bottom of the sea in a single stratum, they would only cover a space of 200 acres. Were it possible, which it is not, to compress and crystallize these lignites into one stratum 6 feet thick, they might then constitute a coal-bed covering 20 acres. All the forests of the Mississippi valley could not furnish to the sea from their river spoils during a hundred thousand years one of the anthracite coal-beds of Schuylkill county. (b)

M. Coquand gives the following *résumé* of the geological formations represented in Roumania:

The Tertiary formation in connection with the clays of the steppes constitutes a continuous and concordant system, in which may be distinguished at the base the nummulite beds representing the great Paris limestone.

1. The Superior Eocene, composed at its base of rock-salt, gypsum, saliferous slates, bituminous schists, and marls with menilites; and above of the "Flysch formation" properly speaking, consisting of alternations of micaceous sandstones (*macigno*), of limestones (*alberèse*), and of argillaceous schists (*galestri*), this superior part being characterized by *Chondrites Turgioni*, *intricatus*, *furcatus*, and by *alveolinus*, the ensemble corresponding to the fucoidal Flysch of Switzerland, the Apennines, Algeria, Sicily, the gypsums of Montmartre, and the saline and sulphurous gypsum of Sicily; also the rock-salt of the high plateau of Algeria.

2. The Miocene stage, which is the first level of petroleum in the Carpathians. The inferior part comprises at its base sandstones and saline slates, with *Cyrena convexa* and sandstones corresponding to those of Fontainebleau, the superior part of sandstones, slates, and limestones corresponding to the molass of Carry and Syracuse; also to the gypsum and rock-salt of Volterra, in Tuscany, and the province of Saragossa, to *Marinen Tegel und Sand* (*néogène* of M. Haidinger); to the *terrain tertiaire miocène marin* of M. Abich; to the *terrain tertiaire inférieur* of M. de Verneuil. The superior part comprises slates and the *grès à congéries* with lignites, amber, and asphalt, and is characterized by *Paludina*, *Achatiformis*, *Congerina subcarinata*, *Cardium*, *Sourieffé*, etc., corresponding to the *Congerischisten* of MM. Haidinger and Hauer (*partie supérieure de leur terrain tertiaire néogène*), to the *terrain tertiaire supérieur* of M. de Verneuil, and to the Pliocene of M. Abich.

3. Pliocene stage, which is the second level of petroleum in the Carpathians. It comprises conglomerates and pudding-stones at its base, and above black slates, producing the steppe formation of Moldavia and Wallachia. It corresponds to the superior marine sub-Apennine formation, to the steppes of the Crimea and the Caucasus, to the desert of Sahara, and the marine deposits of Kertsch with *Ostrea lamellosa*, *Brocchi*; *Chama gryphina*, *Lani*; *Calyptrea sinensis*, and *Linn*.

4. The recent formations comprising the earthy deposits in the environs of Buséo and the recent alluvium of the Danube.

It is noted further, according to M. Coquand, "that the petroleum of Wallachia is in the inferior Tertiary, with mud volcanoes and rock-salt; that the "*Flysch à Fucoids*" is the horizon in Moldavia corresponding to the formation in which it occurs in the Crimea, Transylvania, Galicia, Volterra of Tuscany, the Apennines, Sicily, and Algeria, being everywhere rich in fucoids", who further remarks "that it is only in the slates that it preserves its liquid state, and when it had been brought in contact with permeable rocks, such as sandstones, those rocks imbibed the mineral oil and were changed into asphalt. He accounts for this by assuming that in the porous strata the oil loses by evaporation its volatile principles. He further remarks that the petroleum is not in the rock-salt, but in the slates contiguous to it, rich in fucoids and the remains of marine animals. (c)

In Galicia the petroleum is found saturating coarse and fine sandstones in zones or horizons, the lighter oils being found deepest.

This sandstone is abundantly permeated with limestone; yet in all fissures and on almost all surfaces the products of dry distillation are plainly recognizable, as also earth-wax and tough black maltha, and particularly asphalt. These products of distillation in many places extend even up to the surface, particularly in the northwestern part of the oil-bearing formations. The cavities of asphaltum were known in ancient times, and the thick fluid earth-oil which oozed out upon the surface was sometimes used as a lubricant for the axles of wheels. (a)

The largest yield of petroleum has not been found in the neighborhood of asphalt beds, but farther east, where gas-springs called attention to the probability of reaching petroleum below the surface. It was remarked that the harder the sandstone the greater the pressure of gas and the deeper the source of the oil.

Fig. 7 gives a section from Boryslaw, in east Galicia, to Schodinca. It exhibits a synclinal of schists, standing, where exposed, nearly perpendicular and flanked with sandstones. The wells are sunk in the schists. It resembles a section of the sulphur mountain in California. (See Fig. 6, page 68.)

The conclusions reached by geologists regarding the occurrence of petroleum in Galicia show that the central core of the Carpathians consists of metamorphic rocks, on the flanks of which lie the members of the cretaceous and tertiary formations, consisting of limestones, sandstones, and shales, the latter being, for the most part, rich in organic matter, both vegetable and animal, such as fossil fucoids and fish. In east Galicia and Bukowina heavy beds of black bituminous shales are particularly noticeable. (b) These formations lie in folds, the petroleum occurring under the arches of anticlinals rather than in the troughs of the synclinals.

The facts to be obtained regarding the occurrence of the petroleum of Asia are very few. It appears to be generally conceded that the formation from which the petroleum in the neighborhood of the Caucasus arises is Tertiary, but so far as I can ascertain it issues rather from erratic beds of sand in superficial clays than from any well-defined formation. Lartet appears to regard the bitumen of the Dead sea as of volcanic origin. (c) The petroleum of Java lies in the Tertiary beneath alluvium, which flanks the volcanic core of the island. (d)

Granting that the petroleum of the Niagara limestone at Chicago is indigenous, the invasion of that limestone by steam under high pressure would cause the petroleum to accumulate in any rock lying above sufficiently porous or fissured to receive it. The mingling of oils that contain paraffine and oils that produce asphaltum, and the occurrence of paraffine in large masses in porous strata filled with the remains of fucoids and marine animals that flank the core of crystalline metamorphic schists in Roumania and Galicia, offers the strongest support to this hypothesis. The fact that the eruptive rocks of lake Superior and the metamorphic rocks farther east prevail to such an extent that that vast inland sea has been supposed to be the crater of an extinct volcanic lake lends the strongest support to an hypothesis that regards the vast accumulations of petroleum in western Canada as due to the invasion of strata on the borders of this heat-center, in which the petroleum is indigenous, by a sufficiently elevated temperature to cause its distillation.

It appears to me that mud volcanoes and hot springs are properly regarded as the phenomena attending the gradual subsidence of metamorphic action in the crust of a cooling earth, and that petroleum or maltha is but the accident of such phenomena, when strata containing organic matter are still invaded at a great depth by a temperature sufficient to effect the distillation of their organic content. Gas-springs may also own the same origin, or the gas may escape from deep-seated reservoirs, the product of a distillation long since completed.

The fourth class of solid bitumens occur in great variety. The universal distribution of bituminous material in rocks was noticed in 1823 by the Hon. Geo. Knox, in a paper read before the Royal Society of Great Britain. (e) The occurrence of disseminated bitumen in metamorphic rocks at Nullaberg, in west Sweden, supposed to be Laurentian, has been described; (f) also in the Lower Silurian of south Scotland, (g) in Trap, near New Haven, Connecticut, (h) and in northern New Jersey, (i) all of which are manifestly the result of the action of heat upon the organic matter in stratified rocks. The occurrence of bituminous limestones in France and the valley of the Rhone, and the almost unanimous opinion of the French geologists that they are the result of igneous or metamorphic action, has already been mentioned.

There remain the phenomena attending the occurrence of large veins of solid bitumen in Cuba, West Virginia, and New Brunswick, for which no adequate explanation has been proposed that does not regard them as a product of distillation from deep-seated strata, which has been projected into a fissure formed by the sudden rupture of the earth's crust. Dr. R. C. Taylor examined the vein which occurs in metamorphic rocks near Havana, and gives a section (Fig. 8) of the vein as it is exposed in the working of the mine. He says:

It was evidently originally an irregular open fissure, terminating upwards in a wedge-like form, having various branches, all of which have been subsequently filled with carbonaceous matter, as if injected from below, and that not by slow degrees, but suddenly and at once. (j)

a J. K. K. G. R., xviii, 311.

b Bruno Walter, J. K. K. G. R., xxx, 115.

c B. S. G. F., xxiv, 12.

d Bleekrode, C. N., v, 188.

e Phil. Trans., 1823.

f L. J. Inglestrom: *The Geo. Mag.*, iv, 160.

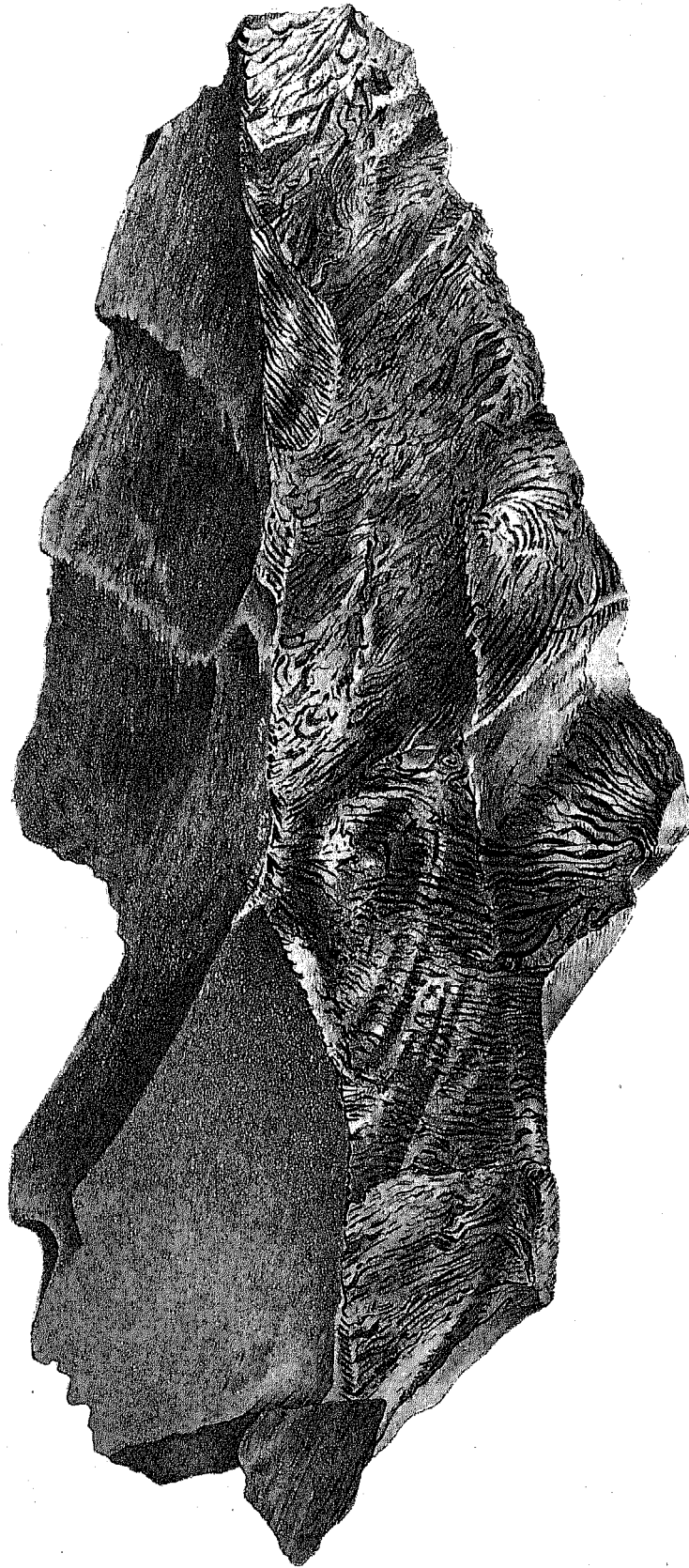
g *Quar. Jour. Geo. Soc.*, xi, 468.

h A. J. S. (1), xxxvi, 114; (3), xvi, 112.

i A. J. S. (3), xvi, 130.

j *Phil. Mag.*, x, 161.

Pl. I.



DRAWING OF A PIECE OF THE HURONIAN SHALE ENCLOSING THE ALBERTITE VEIN IN NEW BRUNSWICK,
SHOWING THE MANNER IN WHICH THE ALBERTITE CLEAVES FROM THE ENCLOSING ROCK.

In 1869 I made the origin of albertite and allied substances the subject of a paper, (a) in which I discussed the views held by others regarding it and compared them with the observations made in New Brunswick and West Virginia by Jackson, Wetherell, Lesley, Wurtz, and others, with my own observation of a vein on the coast of California. This latter vein is exposed on the coast west of Santa Barbara, and stands vertical, cutting the Pliocene and recent sands. With this vein are associated lenticular masses, extending horizontally, from which a sort of talus projects vertically into the sands beneath. The eruptive origin of these deposits is beyond question.

Similar deposits are described by M. Coquand as occurring in Albania, as follows:

The bitumen at Selenitza does not lie in regular beds, but in masses, in the midst of the sandstones and conglomerates that preserve a sort of parallelism, each mass consisting essentially of a central portion of considerable thickness, which gradually thins out in all directions to zero. In no case does the bitumen penetrate the roof above the mass, but was evidently injected from below. Fig. 2 (b) shows a deposit that has furnished an enormous quantity of bitumen. These deposits occur as if during the sedimentation of the rocks at the bottom of the tertiary area the bitumen in a viscous state had filled the depressions in which it has accumulated, remaining pure or being incorporated with the slaty materials with which it is contaminated. A section of the mass corresponds in many cases to a flask filled with solidified water. The aligned basins appear to have been filled successively from the overflow of one into the other. It is evident that the masses, in spite of their irregularity, are parallel with the stratification. Generally the bitumen consists of compact, very homogeneous matters, and next to this variety the bituminous breccia should be mentioned. This consists of beds of gray slate of varying thickness, inclosing angular fragments of bitumen, separated from each other, but which are easily obtained by soaking in water the slate which serves to cement them. This breccia is represented by Fig. 9, often overlying a bed of asphalt, into which it passes by insensible gradations, and seems to form the upper portion of a liquid bath, into which the slate plunged and afterward regained the surface before its entire solidification. Exactly as in a blast-furnace, the slag becomes mingled with the metal in the last products of the tapping, producing a species of magma. More rarely the bitumen rolls itself upon itself (Fig. 10), thus producing spheres analogous to those which invest viscous matters when rolled in water or dust. The structure of them is concentric, resembling pea-stone, but is destitute of any nucleus so far as observed. These envelopes might result from progressive desiccation, the result of which leaves the bitumen divided into thin pellicles, like certain basalts, in which, on cooling, spheres of variable volume are produced composed of concentric coats. The globules are for the most part isolated in the midst of the slate, and are about one-third of an inch in diameter. Another curious form is shown in Fig. 11. It consists of an infinite number of threads crossing each other in all directions, producing a sort of stockwork. Fig. 12 shows a form which differs from the preceding in that the threads instead of being scattered in a capricious plexus are vertical and parallel. The contraction of the sandstone having opened these vertical and parallel vents, the bitumen following filled them, but from above downward. Sometimes the bitumen, as indicated by Fig. 13, is molded in cup-like depressions, which are terminated by a capillary tube. At other times ellipsoidal masses are introduced, some of which are as large as a cannon-ball. They are aligned in positions parallel to the plane of the beds in which they repose. Masses of sandstone are sometimes met inclosed within the bitumen. Such are sometimes observed in beds of coal.

It is to be observed that the threads that sometimes connect the masses of bitumen spring from the side and not from the top of them—a fact that is explained if we assume the ascending mass overflowed horizontally in this particular locality.

A great many bivalves, especially *Cardium*, were observed filled with bitumen. He also discovered a very large *Planorbis* and other species with the interior filled with bitumen. After showing that the material could not have entered the rocks in a fluid state, he says: "It is then in the condition of glutinous bitumen that the maltha primarily entered the formation at Selenitza. There is no evidence of the phenomena of salses, nor solfataras, nor volcanoes, which distinctively characterize the occurrence of petroleum properly so called."

M. Coquand states that there exists at present at one point in the ancient excavations a sort of crater that emits smoke and a great heat, but he assumes that the fire was lighted by the hand of man, which, as in burning collieries, slowly pursue their work of destruction. The clays from which the volatile products are expelled become a sort of brick, sonorous and red, and the sandstones are converted into porcelainites and quartzite, and break at the least shock into a thousand fragments. Fig. 14 represents a section of the rocks in which the bituminous strata occur.

M. Coquand mentions in connection with the bituminous strata solfataras and mud volcanoes, both active and extinct, with which was associated more or less fluid maltha, which is at first very liquid, but soon becomes sirupy, and is finally added to the accumulations of the bituminous cone. The volcanic phenomena assume three forms: First, when inflammable gas escapes through the soil; second, when they escape with water and petroleum, forming craters of bitumen; third, volcanoes emitting hot water (*volcan ardent*). (c)

From the foregoing it will appear that solid bitumen occurs in great abundance, filling variously-formed cavities in the Pliocene strata of Albania, and that maltha accompanies the water of springs from deep-seated strata, often in close proximity to active or extinct volcanic action of the mild forms observed as solfataras, mud volcanoes, or salses.

The great similarity in the occurrence of intruded tertiary bitumens in Albania and California is very remarkable.

No hint is given by Dr. Taylor respecting the age of the rocks inclosing the bitumen vein in Cuba, as at the time he wrote (1837) all metamorphic rocks were called primary. There is little doubt, however, that the vein in

a A. J. S. (2), xlviii, 362.

b See page 32.

c B. S. Q. F., (1), xxv, 35. The precise volcanic phenomenon designated by M. Coquand as *volcan ardent* is not clear. In one case it appears to be an ordinary volcano emitting lava, and in the present case a hot-water volcano; but he afterward remarks that the Tertiary formations in the valley of the Vojutza do not contain the least trace of volcanic action, nor is there a volcanic or thermal spring in the whole country. I presume he refers in this latter sentence to outflows of scorix and lava, and does not include in the phrase *volcanic action* the mud volcanoes and solfataras, which he describes at some length.

New Brunswick and in West Virginia originated at nearly the same time and subsequent to the Carboniferous era, and it is certain that subsequent to that era a great convulsion caused an upheaval that in collapse produced the White Oak anticlinal. Very near the southern end of this anticlinal the vein of grahamite occurs, cutting the horizontal sandstones of the coal measures vertically, but those who mined the vein declare that the material must have welled up from beneath into the fissure the instant it was formed, numerous fragments of the wall-rock being found imbedded in the asphaltum only 12 or 15 feet below the cavities from which they fell, with all their edges and angles sharp and exactly fitting each other. Curious curved lines, resembling those produced when a stone is dropped into mortar, are formed on these horses, suggesting the probability that they fell into a plastic mass that rolled upon them, producing lines of unequal pressure and adhesion that remain after the asphaltum has cleaved from them or the inclosing walls. Moreover, these walls of porous sandstone have not absorbed the bitumen to the thickness of a piece of paper. The significance of these facts was more forcibly impressed upon my mind when I found among a set of specimens from the albertite vein of New Brunswick a piece of the inclosing shale, marked with the mineral in forms almost identical with those observed on the sandstone in West Virginia. Plates I and II are very carefully drawn from specimens from the two localities.

It should be borne in mind that while this subject is one of speculation, pure and simple, it is one that has its valuable consideration outside the domain of scientific inquiry or curiosity, as affecting the sources and duration of supplies of petroleum, its profitable development, and commercial permanence.

If petroleum is the product of a purely chemical process, we should not expect to find Paleozoic petroleum of a character corresponding with the simple animal and vegetable organisms that flourished at that period, and tertiary petroleum containing nitrogen, unstable and corresponding with the decomposition products of more highly organized beings, but we should expect to find a general uniformity in the character of the substance, wherever found, all over the earth.

A mass of polypi undergoing decomposition upon a beach would doubtless saturate the sand with about the same kind of decomposition products as an equal bulk of algae; but when a mass of animal matter, consisting not only of the muscular tissue, but of all the non-nitrogenous substances entering into animal organisms, was thus subjected to decomposition, submerged in water, the product could not fail to be a nitro-hydrocarbon, which upon exposure to atmospheric oxygen would undergo a second decomposition into a greater or less number of the following-named products: carbon, hydrocarbons, ammonia or free nitrogen, carbonic acid, and water. The petroleum of southern California, issuing primarily from Miocene shales, are of precisely this unstable character. (*a*)

The advocates of the chemical theory affirm that they provide for a process the conditions of which are perpetually renewed. It is thus continuous and at present active. On the contrary, if petroleum is the product of metamorphism, its generation is coexistent only with that of metamorphic action; an action which we have no reason to believe has been prevalent on a large scale during the recent period. If we accept this hypothesis, the generation of petroleum is then practically ended.

M. A. Rivière has published a paper on the origin of combustible minerals. (*b*) His opinions are based on his observations of the effect on soil and organic matter in the soil of the leakage of illuminating gas from the pipes in which it is conducted. The effects which he attributes to marsh-gas are, however, due to the condensation of the tarry matter that is dissolved in the escaping gas, the coal-tar products produced at a high temperature not being constituents of petroleum to any great extent. The experiments of Professor Sadtler indicate the presence of minute quantities of benzole in the Bradford oil of Pennsylvania, (*c*) but it was not found by Warren and Storer in the Oil creek oils, its presence in the Bradford oil furnishing an additional reason for supposing it to be a fractional distillate produced under great pressure, and consequently at a comparatively high temperature.

a S. F. Peckham, P. A. P. S., x, 453.

b C. R., xlvii, 646.

c Communication to S. F. Peckham.

Pl. II.



DRAWING OF A PORTION OF THE SURFACE OF A MASS OF SANDSTONE FOUND ENCLOSED IN THE GRAHAMITE VEIN
RITCHIE CO. W.VA. SHOWING THE MANNER IN WHICH THE GRAHAMITE CLEAVES FROM THE ENCLOSING ROCK.